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## HOW TO TEACH CHEMISTRY



# HOW TO TEACH CHEMISTRY,

HINTS TO SCIENCE TEACHERS AND STUDENTS

BEING THE SUBSTANCE OF

Four Lectures

*DELIVERED AT THE ROYAL COLLEGE OF CHEMISTS IN JUNE 1872*

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## P R E F A C E.

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I WAS one of the Science Teachers selected in 1872 to attend a course of laboratory instruction at South Kensington. One of our duties was to take notes of lectures delivered by Professor Frankland, which were subsequently examined by his assistant, and returned to us. Since then my report of these Lectures has been so well worn by borrowers, and I have been so frequently consulted by other teachers on matters comprised within the limits of the 'Elementary Stage' of Subject X., that it appeared desirable to put my notes in a permanent form. This, by the kind permission of Dr. Frankland, is now done, and I trust my fellow teachers will find the work as useful as I have been led to expect. My thanks are also due to Professor Bloxam for permission to use a number of engravings from his valuable text-book of Chemistry.

G. C.



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# HOW TO TEACH CHEMISTRY.

## LECTURE I.

THERE are usually two defects noticeable in the answers sent up at the May Examinations of the Department of Science and Art, chiefly in the elementary stage. First, the pupils' evident ignorance of experimental illustrations; they have heard descriptions of experiments, but have not seen them performed. Secondly, a want of ability to express their thoughts in writing. The present course of lectures to science-teachers is intended to contribute towards the remedy of the first of these defects, by giving hints on the experimental illustrations to be used in teaching.

It is of the highest importance in teaching to exercise and develop the faculty of Observation in our pupils. Most great discoveries have been the result of diligent and long-continued observation, as the history of science amply shows. Yet of all the faculties of the mind this is the most persistently neglected in ordinary schemes of education. Our scholars are told what other people have observed, but they are not taught to observe for themselves. In the teaching of science this ought not to be; and students ought to be shown what to look for, and required to make their own observations.

The experiments necessary to illustrate the instruction for the first stage of the elementary examination in chemistry

should begin with such as exemplify the action of different forces. Familiar instances should be quoted. Of *Heat* cases are common enough. *Cohesion* may be shown by the adhesion of the surfaces of two pieces of plate-glass, very clean and smooth: they can be slid upon one another, and the lower may be lifted by the upper one. The action of the *Electric* force may be illustrated by an excited stick of sealing-wax or glass rod and pieces of paper. *Magnetic* force is exemplified by an ordinary magnet. It should be pointed out that the action of these forces upon matter does not modify the latter in any way, or leave any permanent effect upon it, as far as its ordinary properties are concerned. Illustrate this by the action of the voltaic current (five or six cells) upon a spiral of platinum wire. Cohesion and gravity act upon it; gradually increasing heat, leading to a radiation of light, and a current of electricity are all influencing the wire at one and the same time. But when the action of the last three forces is stopped the original properties of the wire are not in the least altered.

Now, illustrate the *transforming* nature of the Chemical Force, by burning magnesium ribbon or wire (1).<sup>\*</sup> Wire is best, simply on account of its resemblance in form to the platinum in the previous experiment. Show that magnesium resembles platinum in certain of its properties, such as lustre and tenacity. Then cause heat to act upon it in air, holding it in a pair of tongs, at an angle of about 45°, so as to keep it burning, and over a piece of blackened paper, to receive the product of combustion. Contrast the result of heating magnesium with that of heating platinum. One metal is utterly transformed, the other is not at all modified.

Next show further this change of state, as of *liquids into solids*. Take a saturated solution of calcic chloride, mixed with an equal bulk of water. Add to it, all at once, an equal quantity of dilute sulphuric acid (1 to 4), and shake

<sup>\*</sup> These heavy figures refer to the list of experiments given in the Appendix.

gently (2). A sulphate of lime is formed, which 'sets,' so that it will not fall out when the vessel containing it is inverted. Illustrate the change of *gases into solids* by placing mouth to mouth two jars (fig. 1), one containing ammonia gas, and the other hydrochloric acid gas, placing the lighter gas (ammonia) uppermost, and then inverting. Flakes of solid sal-ammoniac settle down in the lower jar. Of the change of *solids into gases* ordinary gun-cotton is a very

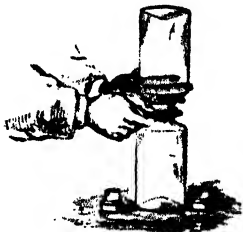


FIG. 1.

good illustration: explode it with a hot wire. *Changes of colour* are not only very good but very attractive illustrations. Make magenta before your class. Put a pinch of powdered corrosive sublimate in a test-tube and moisten it with aniline, so as to make a thick paste, an excess of aniline being avoided. This mixture must be gradually heated, and the development of colour may be observed. It is too intense to show well unless diluted with alcohol. If allowed to cool the magenta may be dissolved out with methylated spirit; if time presses the hot test-tube may be dipped into a test-glass containing methylated spirit. This fractures the tube, and some of the colouring matter is dissolved out. Contrast the splendid colour of the magenta with the dull colour or no-colour of the aniline from which it has been produced.

The *points of difference* between the action of the chemical force and of other forces should be exemplified. Most other forces act at appreciable distances. *Heat*.—Place a piece of freshly-cut phosphorus on a tile; support over it on a brick, at about three inches' distance, the red-hot end of a poker: the phosphorus ignites (3). The burning phosphorus should be covered by a bell-jar or inverted beaker, to prevent annoyance from the fumes. *Electricity*.—A glass

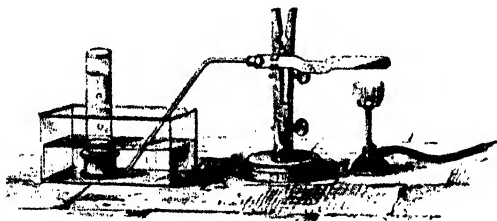


rod, excited by friction with silk and amalgam, will attract a suspended rod of light wood or long thin cylinder of paper (4).

In contrast with these facts, show that the chemical force will only act at *inappreciable distances*. A mixture of finely powdered loaf-sugar (1 pt.) and potassic chlorate (2 pts.) will ignite on actual contact with a glass rod dipped in strong sulphuric acid, but not so long as any measurable distance intervenes between the acid and the mixture (5). The state of liquidity, as tending to promote mobility of particles, is extremely favourable to chemical action. This may be produced in two ways—by solution and by fusion. Illustrate the first by a common Seidlitz or effervescing powder, as tartaric acid and sodic carbonate, which may be mixed dry for years without action occurring; but when water is added there is immediate and violent decomposition. In the dry way a deflagrating powder may be used (well-dried potassic carbonate 2 pts., sulphur 1 pt., and nitre 3 pts.) which liquefies by heat and explodes violently in the act of combination. A platinum capsule is best for this experiment, but an iron sand-bath dish may be used. In preparing this powder the ingredients must be finely powdered separately, well mixed on paper with an ivory spatula, and it should be kept in a well-stopped bottle, as it is hygroscopic.

Next may be shown illustrations of the five modes of chemical action. (a) *Union*.—A jar of hydrogen is to be placed mouth to mouth with one of chlorine, and the contents allowed to mix (not in strong daylight), and exploded by ignition at a lamp (6). Draw attention to the white fumes which are formed. (b) *Displacement*.—Bright iron, as the blade of a knife, may be dipped into a solution of any copper salt (7). The chloride is best if symbols are used in explanation, being of simple composition. (c) *Exchange*.—Add solution of potassic iodide to one of mercuric chloride, and stir while mixing (8). (d) *Rearrangement*.—

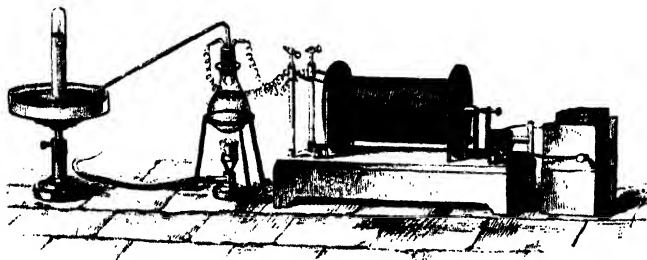
There is no good inorganic example. A familiar case may be shown by heating a test-tube, containing white of egg, in a water-bath (9). As this occupies a few minutes it is well to have a tubeful already prepared. (e) *Resolution*.—Decompose red mercuric oxide by heat (10), in a piece of



combustion tube, with bend to retain globules of mercury (fig. 2), showing the condensed metal, and also immersing a glowing taper in the oxygen produced.

It will next be advisable to select some well-known substance for further study. *Water* may be first taken, as most familiar, and one of which most people already know something. Its familiarity is quite a counterpoise for its greater complexity as compared with hydrochloric acid. Notice its three states of aggregation — solid, liquid, gaseous. As a gas it neither burns nor supports combustion: show this with a jet of steam or water-gas, which will not burn, but extinguishes a taper. On heating, ice melts to water; water heated becomes steam—what if we heated this steam still further? The electric spark supplies us with a handy means of applying a most intense heat (fig. 3). By passing this spark-stream through steam it becomes converted into a gas, which, unlike water-gas, is uncondensable in cold water, and may be collected in a test-tube. This gas, unlike steam, again, burns and even explodes. It is best to act at first with such forces as heat and electricity. Next show

(fig. 4) that by the voltaic current the same gas can be produced from liquid water slightly acidified with sulphuric acid (11). In the voltameter employed in this experiment, no part of the platinum surface should come into contact with



the mixed gases, lest contact-action should produce an explosion. This experiment should be repeated, and the gases coming off at both electrodes collected separately. There are various forms of apparatus for this purpose. The ordinary

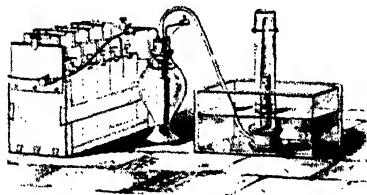


FIG. 4.

electrolysis tubes are perhaps best, especially for large classes. A very good form of apparatus is that devised by Professor Hofmann (fig. 5). But the distance between the electrodes may necessitate the use of greater electric power, or an increase of conducting power of the liquid. The V tube with platinum electrodes is also very useful. The distinctive

properties of the two gases, when thus obtained, should be demonstrated, and the students informed of their names. It will be enough to re-ignite a glowing cedar-splint with the oxygen, and to show that hydrogen burns by igniting it at a light of low luminosity, such as that afforded by cotton-wool on wire, dipped in spirit of wine.

Lastly, the chemical force should be caused to act upon

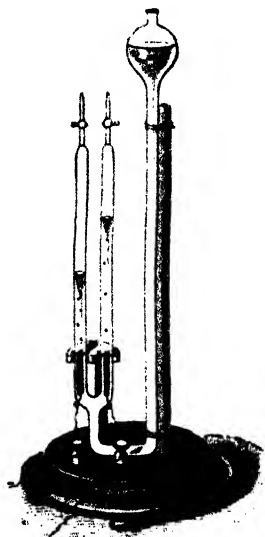


FIG. 5.

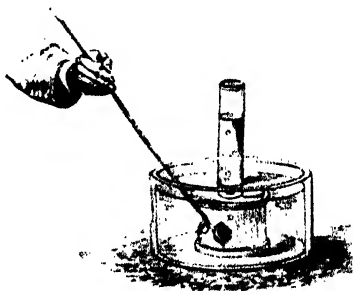
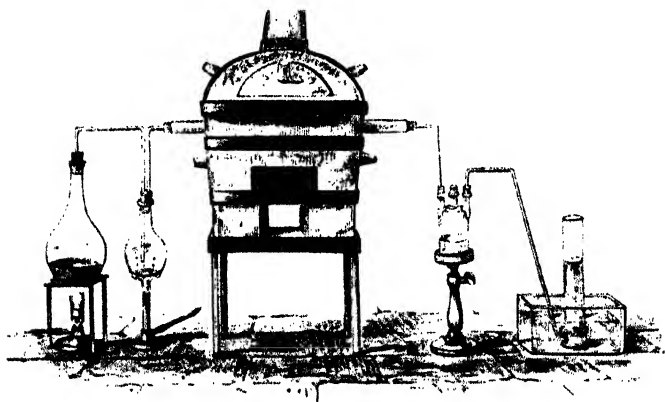


FIG. 6.

water. 1. Drive out hydrogen by an alkali-metal (12). First illustrate by throwing a piece of potassium on the surface of some water; then collect hydrogen displaced by sodium, carefully guarding against explosions (fig. 6). The 'sodium spoon' and use of wire-gauze, unless quite new, is objectionable; it is safer to use short pieces of leaden tube,  $\frac{1}{4}$  in. diam., closed at one end and filled with sodium,

lying in the pneumatic trough beneath an inverted gas-jar full of water. 2. Drive out oxygen by chlorine (26). This interesting experiment is somewhat troublesome to prepare, and the apparatus should be fitted up carefully beforehand (fig. 7). Chlorine is first generated in the ordinary manner in a flask fitted with a safety-funnel. The gas is led into a wash-bottle containing cold water, to intercept hydrochloric acid, and then into a flask of water kept boiling. From this a mixture of chlorine and steam is led



into an empty bottle, to detain the condensed steam, the remainder with the chlorine being conducted into a porcelain tube, passing through a furnace.\* The tube should be slightly inclined, so that if steam should condense in it before reaching the hot portion the water so formed may trickle back. The larger the heated surface in the

\* I have found that iron tubes enamelled inside and packed with broken porcelain are quite as useful as the tubes usually employed, and are not liable to break. I do not know how long they last, but have used one in a dozen experiments, and it is still sound. —G. C.

tube the better; it may be packed with pieces of pumice-stone or broken porcelain. A bright red heat should be maintained. From this tube the gases are conducted into a wash-bottle containing caustic soda in solution, to retain hydrochloric acid and free chlorine; and the oxygen may be led off and collected over water in the usual manner. All the wash-bottles should be three-necked, and be fitted with safety-tubes; and before heat is applied every cork should be examined and proved to be air-tight.

In this and many other experiments, where an irritating gas such as chlorine is used, it is expedient to have some contrivance whereby the escape of the gas into the room may be prevented. For this purpose a T tube may be employed, being interposed between the chlorine generator and the first wash-bottle, its lower limb dipping into a solution of caustic soda. By using a pinchcock the gas may be led into the alkaline solution and absorbed, or it may be allowed to pass through the apparatus, as described above.

### *Addenda to Lecture I.*

The following are experiments further illustrating the points touched upon with respect to chemical action :—

Two *solids*, sugar and German yeast, become *semi-liquid* when rubbed together in a mortar. A mixture of alum and acetate of lead behaves similarly. Iodide of nitrogen, exploded by the touch of a feather, illustrates the conversion of a *solid* into *gases*. To show *changes of colour* solutions of the following salts may be mixed in test-glasses: (1) Plumbic acetate with potassic chromate gives a yellow; (2) ferric chloride with potassic ferrocyanide gives a blue; (3) ferric chloride with potassic sulphocyanide gives a dark red. If the solutions are rather weak they are nearly colourless, and the effect on mixing is more striking.

The value of *fineness of division* in promoting chemical action is well illustrated by opening a pyrophorus and shaking out the

contents, which take fire as they fall out, exactly as a meteor inflames as it rushes through our atmosphere. The preparation of pyrophori is described in the next lecture.

The five *modes of chemical action* may be thus further exemplified; and attention should be drawn to the phenomena of light, heat, &c. which are occasional accompaniments:—

1. *Union*.—A piece of perfectly dry phosphorus is laid upon a little powdered iodine placed on a tile; they combine with flame and dense fumes, which should be confined with a bell-jar or inverted beaker. Powdered antimony may be shaken into a jar of chlorine; this should be done in a stink-cupboard, or, at any rate, the jar should be removed as soon as possible. Phosphorus, sulphur, charcoal, or iron may be burnt in oxygen. A jar of oxygen and one of nitric oxide may be put mouth to mouth; or ammonia and hydrochloric acid gases may be similarly caused to combine.

2. *Displacement*.—Sodium may be employed to displace hydrogen, which may be ignited. Slaked lime, rubbed with sal-ammoniac in a mortar, displaces ammonia, which may be smelt.

3. *Exchange*.—Any experiments involving the production of a precipitate on mixing two solutions may be added to the one in the text. Baric chloride and sodic sulphate, argentic nitrate and sodic chloride, plumbic acetate and potassic iodide are good mixtures of this kind. Ferric chloride and potassic sulphocyanide give a red coloration; and cupric sulphate with hydrochloric acid changes from blue to green, but this cannot well be seen by gas-light.

4. *Rearrangement* cannot be better shown than by boiling white of egg.

5. *Resolution*.—The explosion of gun-cotton by touching with a hot wire, or of iodide of nitrogen by contact with a feather, are good illustrations. No other explosion should precede that of iodide of nitrogen, as it is so unstable that even a slight concussion of air will decompose it.

## LECTURE II.

HAVING thus demonstrated that water is composed of two kinds of matter, both gaseous—one inflammable, the other not so—it will be well, for an elementary class, to proceed to the detailed study of these gases. An advanced class might with more advantage proceed to a similar analysis of hydrochloric acid, ammonia, marsh-gas, and ammoniac chloride.\*

First, as to the preparation of these gases. The modes hitherto shown are too expensive and inconvenient for common use, though highly favourable for the particular object in view when they were used. Cheap and handy methods must now be exhibited, and very ordinary apparatus, so that pupils may repeat experiments at home.

*Hydrogen*.—1. The principal method of preparing this gas is by acting on an acid with a metal, as with zinc and sulphuric acid (13). A Woulf's bottle or even a single-necked bottle, with two-hole cork, fitted with funnel and delivery-tube, is employed (fig. 8). Repeat the ordinary boy's experiment of burning the gas through a piece of tobacco-pipe as it is generated. Give a warning against accidents, and illustrate how easily one may happen, by designedly producing an explosion. For this purpose fit a soda-water bottle with a perforated cork, without a tube, or with only a quill, so that if it flies to the ceiling and falls it will do no harm. Place zinc in it, pour in some dilute sulphuric acid, and hold a lighted taper to the orifice until an explosion occurs. Repeat this with the same apparatus, but allow a

\* See Hofmann's 'Modern Chemistry.'



sufficient lapse of time, so that the gas may burn safely.

2. Show that a metal—*e.g.* zinc—may act on an alkali such

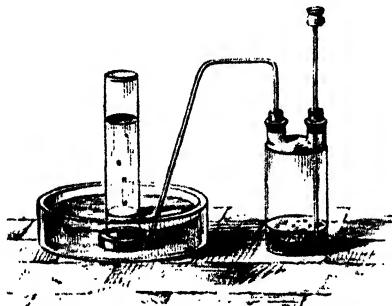


FIG. 8.

as caustic soda, and displace hydrogen (14). The alkaline solution must be concentrated, and the zinc in the form of turnings, and heat must be applied: the gas comes off slowly. 3. Show that other acids besides sulphuric, as hydrochloric, may be similarly decomposed with evolution of hydrogen. In each case collect the gas and burn it, to show its identity.

*Properties.*—Inflame the gas from a jet. Illustrate its lightness (16) by means of a small balloon or soap-bubbles, or by a light bell-jar or beaker mouth downwards, counterpoised on a balance: on pouring upwards a jar of hydrogen into the bell-jar it will rise, owing to a diminution in weight (fig. 9). If the electric or lime light can be procured—or even a magnesium lamp—the shadow of a stream of hydrogen should be projected upon a sheet of white paper. A wide tube should be used, and it should be deflected downwards. Two jars filled with the gas should be left open for twenty or thirty seconds, one having the mouth downwards, the other its mouth upwards (15). Then apply a light, to show first that the gas has escaped from the one, and then to

prove by its ignition that the inverted one still contains the greater part of its gas, only a little air having become



mixed with it. Invert another jar of the gas, and ignite it at the mouth, pushing the taper up into the unburnt gas (17), to show that though the gas burns it will not support ordinary combustion (fig. 10). The taper can be re-lighted at the mouth of the jar. Ignite the gas at the mouth of a jar standing on the table, and point out that the light gas rushing upwards is burnt more quickly than in the previous case.



FIG. 10.

*Oxygen.*—Show the substances from which this gas can be prepared: mercuric oxide, potassic chlorate, and manganic oxide. 1. Prepare a small

quantity from mercuric oxide (26). 2. If circumstances permit show elimination of oxygen by the action of growing plants (mint is best), immersed in an inverted flask full of water saturated with carbonic acid gas, and exposed to sunlight. One or two days' exposure in spring and summer and four or five in winter will be necessary. This illustration is very important, as it explains the natural production of oxygen from the products of combustion and respiration. 3. Show the preparation of oxygen from potassic chlorate (a) alone and (b) mixed with one-sixth or one-tenth of its weight of black oxide of manganese, in the last case washing, and using wide tubes to suit the rapid evolution of gas. Set these two experiments going simultaneously, to show the comparative rapidity of the processes. Having collected specimens of the gas from various sources, prove their identity by similarity of behaviour with a glowing spark.

*Properties.*—Oxygen re-lights a glowing wick (27). Use cedar splints, or green tapers coloured with copper; the oxide of copper causes the wick to glow longer. Phosphorus burns brilliantly (28), and when the heat volatilises it a flash of light fills the whole vessel, owing to the points of contact between phosphorus and oxygen being indefinitely increased. For this experiment a dry flask of oxygen is best, and the phosphorus must be dried. Moisture causes spurting, and will probably break the flask. Iron or steel must be burnt in oxygen (29). A bundle of thin wires may be held in the flame of a Herapath blowpipe urged by a stream of oxygen from a gasholder or receiver of the condensed gas.

Notice that in these cases a preliminary heating is needful for oxidation, but that it is not, however, necessary in some other cases. Coals containing pyrites when moist oxidise and burn, as also does cotton-waste when oily. Fires thus arise sometimes, the phenomenon being called 'spontaneous combustion.' The similar action of 'pyro-

phori' is owing to their fine state of division. Tartrate of lead carbonised in a glass tube and sealed up makes a 'lead pyrophorus;' when the tube is opened and its contents shaken out they burn with a red glow. Zinc-ethyl inflames when exposed to air, with formation of heavy fumes of zincic oxide.

*To prepare Zinc-ethyl.*—Take a piece of combustion tubing 12 or 14 in. long, sealed at one end, and containing at the closed end 3 inches in depth of well-dried granulated zinc. Bend the open end twice at right angles, expel air by heating, and introduce the open end into a mixture of 3 vols. ethylic iodide and 2 vols. common ether, anhydrous (recently distilled over potassic carbonate). Let enough of this be drawn back to nearly cover the zinc. Seal the tube and cut it off at 8 inches or so from the closed end. Immerse the sealed tube in a water-bath for five or six hours, and take it out when crystals appear within. Envelope the tube in a cloth, open it, and connect with a good length of  $\frac{1}{4}$  in. tube. Distil the crystals at a gentle heat, and collect zinc-ethyl in small tubes, which should be sealed up and kept for use.

The re-combination of hydrogen and oxygen to form water may now be shown. Explode a mixture of two volumes of hydrogen with one of oxygen in a soda-water bottle, to show the violence of their combination (30). Small collodion balloons, tied with nitre-cotton and a scrap of gun-cotton, to serve as a fuse, may be filled with this explosive mixture, and allowed to rise; they explode in the air without danger. Soap-bubbles may be blown with the mixed gases by means of a bladder and a pipe, and explode on being ignited. If a Cavendish's eudiometer (fig. 11) can

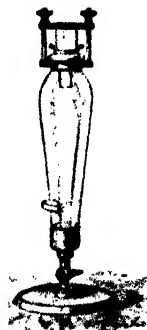


FIG. 11.

be obtained the explosion should be effected with it. In this case the flash of light caused by explosion should be noticed, since the *same combination* in case of bubbles fails to give it. This is owing to the pressure exerted. When the gases are not suffered to expand, there is light; when expansion is allowed, the steam produced is only one-tenth the density of the atmosphere, and there is no light. The density of the ignited medium influences the amount of light. Thus, with attenuated hydrogen and carbonic oxide we have pale flames. The dense vapours of phosphorus, zinc, and mercury give much light when ignited. Solids give most light in combustion.

There is at least one quantitative experiment to prove

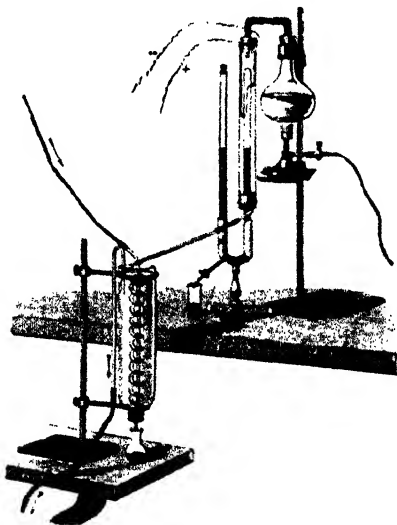
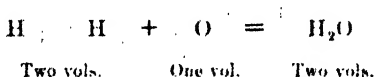


FIG. 12.

the composition of water which should be performed before the class. This is, to show that two volumes of hydrogen

combine with one volume of oxygen to form two volumes of water-gas. The apparatus necessary is a form of eudiometer provided with a jacket, devised by Hofmann (fig. 12). A mixture of hydrogen and oxygen, in the correct proportions, is introduced into the closed end and raised by means of the vapour of fusel-oil passed into the jacket to a temperature of about  $130^{\circ}$  C., when the level of mercury being equalised in each limb, an indiarubber ring is adjusted round the jacket to show the volume. Combination may now be effected by the electric spark, the open end of the eudiometer being corked tightly, and a cushion of air being left to moderate the force of the explosion. Mercury is now poured in to restore the level, on which it will be observed that the volume of uncombined gases has been condensed into two-thirds of its volume of steam. This may be well illustrated to a class by the employment of cubical canisters packing inside a double cube, so as to express the following formula:—



This fundamental fact is thus absolutely *proved* to students.

### *Addenda to Lecture II.*

In preparing hydrogen for experiment care should be taken that the gas is free from any admixture of air. The simplest method of ensuring this is by collecting a few test-tubefuls of gas and igniting them. So long as air is mixed with it there will be a slight explosion, but as soon as only pure hydrogen comes off it will burn quietly. A neat method of showing the explosion of hydrogen mixed with air is, to collect a stoppered jar full and set it upon three blocks, so that when the stopper is removed and the gas ignited, air may enter at the bottom and mingle with the hydrogen

as it is being burnt. The combustion is very rapid, and terminates with a violent explosion (fig. 13). The neck of the jar must not be too wide, otherwise the explosion will not occur.

The diffusion of hydrogen—though strictly a demonstration reserved for advanced classes—may be used as an auxiliary illustration of its lightness. For this experiment a diffusion-tube is needed, which is a long glass tube open at one end and closed within an inch of the other by a porous plug. When in use, the plug must be kept perfectly dry. The tube may be filled with hydrogen by displacement, first closing the top of the tube by a cork, so that no hydrogen may escape through the plug. On then placing the open end of the tube in coloured water, the rise of the



FIG. 13.

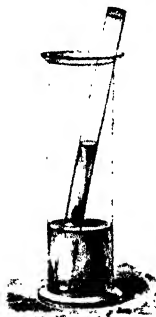


FIG. 14.

liquid on removing the cork shows that the hydrogen escapes through the porous plug more rapidly than the air enters the tube in the opposite direction (fig. 14). The experiment may be reversed by dipping the open end of the tube into water, and lowering a cylinder of hydrogen over the plugged end (fig. 15). The diffusion into the tube in this case is so much in excess of that out of it, that bubbles are forced through the water as if they were violently blown out of it.

It will be well to prove by an experiment that when substances are oxidised they increase in weight. For this purpose a finely-divided metal may be taken, such as precipitated copper or reduced iron. Forty or fifty grains of metal may be weighed out into a

porcelain or platinum crucible, and carefully counterpoised in a balance. On heating to low redness in the Bunsen flame the metal

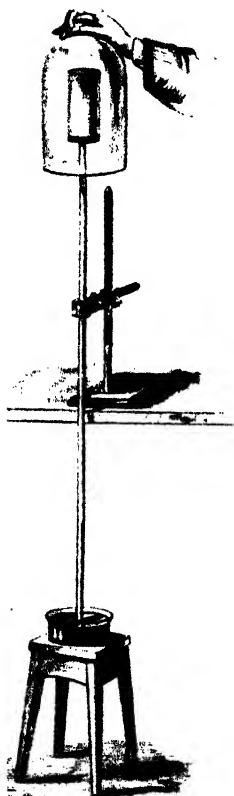


FIG. 15.

is oxidised and by re-weighing when cooled an increase of weight amounting to 10 or 15 grains is observed. If a very good specimen of iron reduced by hydrogen can be secured (that usually sold is not good enough), the ignition may be effected on the balance itself, by simply setting light with a match to a small heap of the metal, which will burn rapidly with a dull red glow: the pan of the balance will rise for an instant, and then quickly sink. Another experiment illustrating the same fact is the familiar one of burning a candle and absorbing the resulting water and carbonic acid by caustic soda, but this is far more troublesome than the illustrations just mentioned, which are, indeed, also much neater.

It is advisable to prove that manganic oxide, when heated with potassic chlorate to prepare oxygen, remains unaltered. This is simply done by dissolving out potassic chloride and filtering off the solution, preserving the manganic dioxide for examination.

The leisure afforded to science-teachers by the summer vacation should be utilised in the preparation of things likely to be re-

quired during the winter, such as the pyrophori above-mentioned. Lead pyrophori are thus prepared:—Precipitate, by means of bitartrate of soda from a solution of acetate or nitrate of lead,



plumbic tartrate, which should be dried at a low temperature. A number of tubes of hard glass about six inches long, and sealed at one end, should now be about one-third filled with the tartrate, and drawn out at the open end. Then, one after another, these should be heated in the Bunsen flame until no more steam or other vapour issues (fig. 16), when the open end can be sealed rapidly. When used, one end is notched with a file and broken off, and the finely-divided carbon and lead shaken out into the air, burning as it falls. If shaken into a white plate it can be seen that litharge is produced.



FIG. 16.

The method described above for preparing zinc-ethyl—also a very good pyrophorus—does not give a large quantity. The following plan is one which does not involve the use of any apparatus beyond what most science-teachers can command, and may be

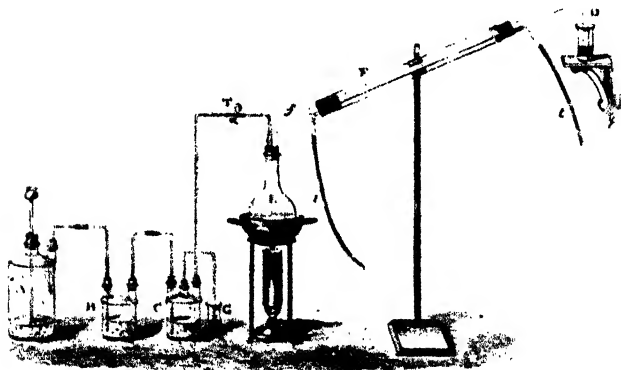


FIG. 17.

adopted when a small stock is to be made. Fit up the apparatus represented in fig. 17, consisting of a carbonic acid generator (A), two drying bottles containing strong sulphuric acid (B, C), a half-pint flask (E) upon a water-bath, and a Liebig's condenser

(F), through which cold water is kept running by means of the tubes *tt*. The presence of atmospheric air and of moisture is to be very carefully guarded against. Eight hundred grains of zinc, perfectly dry and freshly granulated, is to be put into the flask *r*, and the whole apparatus filled with dry carbonic acid gas. Then 400 grains of ethylic iodide, absolutely free from moisture, is

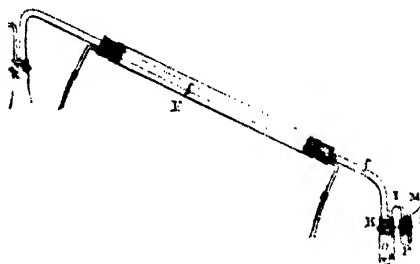


FIG. 18.

poured upon the zinc, and a little more carbonic acid passed through, after which the current is cut off by closing the nipper-tap *r*, when the gas escapes through *a*. Escape of carbonic acid from the flask is prevented by the end of the tube *f* being under mercury in *b*. The flask is now heated by the water-bath, and the iodide of ethyl distils, but is condensed and flows back, until in about five hours it is converted into zinc-ethyl. Then a slow current of carbonic acid is again allowed to pass by opening the tap *r*. The condenser is reversed (fig. 18), and the tube *f* is passed into the short test-tube *a*, which is also fitted with the siphon *t*, connecting it with the smaller test-tube *r*, whose cork is also furnished with a short piece

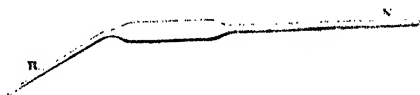


FIG. 19.

of rather wide tube (*l*). A number of small tubes (fig. 10) must be prepared for the reception and preservation of the zinc-ethyl. The bent neck (*r*) of one of these is passed down *l* into *r*, its other end, *x*, being connected with a carbonic acid generator, the gas

being dried of course. Carbonic anhydride being again caused to fill the whole apparatus, the pinchcock, *t*, is closed and the flask *E* heated by a sand-bath, so as slowly to distil zinc-ethyl into the tube *o*, the supply of carbonic acid being kept up through *M* *N*, the excess escaping by *L*. To fill the small tube the end *N* is sealed by the blowpipe flame, and the longer limb of the siphon is pushed down into *o*, so as to dip into the liquid. On opening the tap *T* carbonic acid gas presses some zinc-ethyl over into *p*, so that the end *n* of the small tube dips into it. The bulb *M* is warmed by a spirit-lamp, so as to expel gas, and on cooling zinc-ethyl is sucked up into it, and the tube may be withdrawn and quickly sealed. Great care is necessary throughout, on account of the spontaneous inflammability of zinc-ethyl. (Bloxam's 'Chemistry.')

The flash of light caused by the combination under pressure of two volumes of hydrogen mixed with one volume of oxygen may also be observed if the explosion is effected in a soda-water bottle. For this purpose the mixture obtained by electrolysis is best.



Another quantitative experiment which should, if possible, be shown to a class is that which proves the composition of water by weight. Only approximate accuracy can be obtained in most cases, but the illustration is too important to be omitted. Fig. 20 represents the apparatus necessary for this demonstration. Hydrogen is generated in the usual way from zinc and dilute sulphuric acid in the bottle *h*, and is then passed through solution of caustic potash (*p*), to remove sulphuretted hydrogen; then through a U tube (*s*) containing pumice saturated with a strong solution of argentic nitrate, to remove arsenic and antimony; and lastly through two similar tubes (*rr*) containing pumice soaked in strong oil of vitriol, which thoroughly dries it. The gas then passes over

cupric oxide in the bulb *c*, and finally through the bulb *g* and the tube *i*, containing pumice saturated with oil of vitriol. First, the bulb *c* with its contents must be accurately weighed, also the bulb *g* and tube *i*. Then, all the connections being made, the whole apparatus is to be filled with hydrogen, when the oxide of copper may be heated by a spirit-lamp. As the reduction proceeds water is condensed in *g* and *i*. When the operation is over and the bulb *c* is cold, it must be weighed: the loss in weight represents oxygen. The gain in weight of *g* and *i* is water. The difference between loss of oxygen and gain of water is of course hydrogen. The chief precaution necessary in this experiment is to avoid heating the cupric oxide until all the air in the apparatus is displaced by hydrogen.

When explaining the nature of combustion to a class it is well to show by experiment that gases not usually classed as supporters of combustion may be so under certain circumstances. A simple method of showing this is to melt some potassic chlorate in a phosphorus-spoon mounted on a stand, and when it is in full fusion to invert quickly over it a jar of hydrogen. A small explosion occurs at first, but there is no danger, and the flame of oxygen given off from the chlorate burning in the atmosphere of hydrogen is distinctly observed. Other methods of illustrating this, as by burning oxygen or air in an atmosphere of hydrogen, are also available, but the experiment described is the least troublesome, and this fact, where time is an object, is important.

## LECTURE III.

HAVING now decomposed water (1) by the electric spark and (2) by the galvanic current, (3) collected the separate gases, and (4) reunited them, how are we to prove to students that the liquid thus formed is really water? A convenient mode of preparing water from its elements is by burning a jet of dry hydrogen in air, and condensing the produced vapour (31). A small quantity of water is thus procured. Inform the class (and illustrate it) that potassium will not burn on the surface of any neutral liquid except water. Prove that the condensed liquid is neutral (32), and burn potassium upon it.

Here the properties of water may be conveniently studied. If any way possible, its *colour* should be shown. A long, clean zinc pipe (12 to 16 feet long by 3 in. diameter), with glass plates closing the ends, and half-full of distilled water, may be so arranged as to be looked through, or so that a light may be cast through it on a white screen. The stratum of air will be perceived to be colourless, and the stratum of water will be observed to be of a delicate blue-green, similar to the tint of the Swiss lakes and of some Gloucestershire waters on oolitic soil. The canal at Stroud, fed by springs, is of this colour sometimes. Organic matter, being usually yellow or brown, first neutralises this beautiful colour of pure water, then tints it of its own colour.

*Ozone*.—This allotropic form of oxygen may be prepared by the action of phosphorus on moist air (33). Two or three gas-jars should have a little water at the

bottom, with pieces of freshly scraped phosphorus in it, in contact with air. Leave them, covered, for about half an hour. The quantity of ozone yielded is small, but quite enough, if the phosphorus has not been left too long, to liberate iodine from starch-paper dipped in solution of iodide of potassium. This test should previously be explained to the class. Phosphorus appears first to transform oxygen into ozone; then, by farther exposure, the ozone oxidises phosphorus.

*Hydroxyl*.—This may be and should be prepared before the class, by the action of carbonic anhydride upon water and baric peroxide. The gas may be prepared by any apparatus giving a constant stream (figs. 43 and 47), and, after washing, it should be led into a beaker containing distilled water and baric peroxide, kept stirred. A dilute solution of hydroxyl thus prepared is sufficient for most experiments. If a stronger solution is wanted it must be concentrated over sulphuric acid *in vacuo*, or purchased. Show that strong hydroxyl containing a little caustic soda, when gently warmed, gives off oxygen, and that water is left; collect the gas (35). Show that oxide of silver, when treated with hydroxyl (strong), is reduced to the metallic state, with evolution of oxygen, while hydroxyl is also reduced to water\* (36). This experiment by Sir B. Brodie confirmed the molecular hypothesis. Illustrate, with the aid of this experiment, the composition of molecules. Free oxygen is oxide of oxygen. An excess of either hydroxyl or argentic oxide remains undecomposed in this experiment. Show how blackened paintings (from action of sulphuretted

\* Experiments such as this are frequently objected to as too expensive. A little care would obviate this. Silver, gold, and platinum salts, after they have been used in experiments, should not be thrown away, but be put into the residue bottles which ought to be in every laboratory. Their subsequent conversion into reagents saves the expense of buying more, though it involves a little trouble. This very trouble may be utilised by giving practice to a senior student.

hydrogen on the lead pigment) are restored. Use a piece of lead-paper which has been exposed to sulphuretted hydrogen and dip it in hydroxyl or brush the liquid over it, thus changing the black sulphide of lead into the white sulphate (37, 38).

Now *hydrochloric acid* may be submitted to an examination similar to that by which we have learnt so much respecting water. Use a jar of the gas to show its properties. It is colourless and transparent; it will not burn nor support combustion (24), it fumes in moist air, reddens blue litmus-paper, but does not bleach carmine-paper. Here explain fully acid and alkaline reactions and use of test-papers. Have ready prepared equivalent parts of hydrochloric acid and caustic soda in weak solution. Show one to be acid, the other alkaline, and the mixture of the two neutral (23). This experiment should be prepared beforehand with great care. Show hydrochloric acid gas to be soluble in water (25). Use a stout jar, with a thick glass cover. Hold the jar firmly, and withdraw the cover, by a sliding motion, under the surface of water, to get quick absorption by a jet of water into the jar. There is the chance of a thin plate breaking by pressure, also of the jar being forced downwards. It is necessary to prove the solubility of the gas, because, in its electrolysis, which must next be effected, a solution is used (20). Collect the mixed gases into which hydrochloric acid (the strongest of commerce) is decomposed in the voltameter. Manifestly this mixed gas is not hydrochloric acid, for it does not dissolve much in water; it bleaches moist carmine-paper, and burns with explosion when lighted.

There is a little difficulty in demonstrating the relative proportions by volume of the two gases which compose this mixture, for one of them is considerably soluble in water. The decomposition must be started long enough beforehand for the liquid to be pretty well saturated with chlorine, and then the gases may be collected separately. If Hofmann's

apparatus be used, a variety of it with caoutchouc tube may be employed, which enables us to equalise the pressure in all three limbs, for the greater the pressure the more gas is dissolved. Having collected the gases separately, their properties should be briefly examined. One is found, by its ready inflammability, to be our old friend hydrogen; the other is non-inflammable, and possesses bleaching powers—it is *chlorine*.

*Chlorine* should now be prepared by chemical methods, and its properties fully demonstrated. The usual method, by manganic dioxide and hydrochloric acid (fig. 21), may

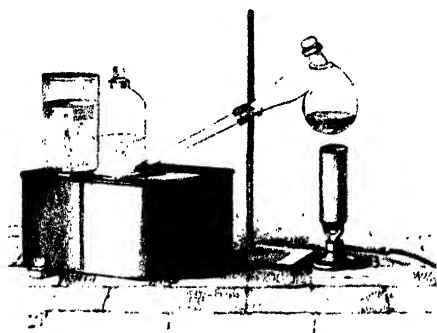


FIG. 21.

be employed, with three-way tube to prevent annoyance (18). Point out the colour of the gas; its irritating smell will indicate itself. 1. Show its action on powdered arsenic (or antimony, which is less poisonous), sifted into the gas, at ordinary temperatures, from a muslin or gauze bag. There is some risk of fracturing the thick bottom of an ordinary gas-jar by the heat of union; hence a layer of sand may be placed at the bottom as a protection, or a flask of thin glass may be employed. 2. Burn sodium in chlorine. Heat the metal to fusion in a deflagrating ladle by Herapath's blowpipe. On lowering into chlorine there



is vivid combustion, with fumes of sodic chloride. 3. Show spontaneous combustion of phosphorus in chlorine. Notice the slight evolution of light as compared with that evolved by its burning in air. The amount of heat generated is but small; and though phosphorous chloride is a dense vapour, not much light is produced. If, however, the chlorine be previously passed through a tube heated to redness, and over phosphorus heated in a bulb tube, much more light is emitted. 4. Burn a jet of coal-gas in chlorine; its flame is more luminous and smoky than usual. An ordinary taper is more smoky still, and burns with a lurid red flame, speedily going out. It is evident that chlorine will thus support the combustion of hydrogen, but not of carbon. Burn a jet of hydrogen, and try to burn a piece of charcoal in the gas, to prove this. 5. Show the bleaching power of chlorine (19). Use weakish solutions of indigo, cochineal, magenta, and aniline purple, and add to them a solution of chlorine. Colourless or nearly colourless substitution products are formed. Colours with a basis of carbon, such as printing-ink, are not bleached by chlorine.

Hydrochloric acid may now be reproduced by burning a jet of hydrogen in an atmosphere of chlorine (21). A large flame is given, and fumes of hydrochloric acid ascend in the moist air.

Chlorine has its affinities stimulated by light, as those of oxygen are urged by heat. This may be shown by exploding the mixture of hydrogen and chlorine derived from electrolysis of hydrochloric acid, and sealed up in lead-glass bulbs. These, of course, must be kept in the dark. To explode them a box must be provided, to prevent scattering of the fragments. The actinic light of burning magnesium wire is sufficient to effect the combination. By producing a similar combination in a closed vessel capable of withstanding the shock, the volumetric constitution of hydrochloric acid may be demonstrated. For this purpose strong glass tubes,  $\frac{3}{4}$  in. wide, with stopcocks at each

end, are filled with mixed hydrogen and chlorine in equal volumes. One-half of this mixture—that is, its chlorine—is soluble in caustic soda; and this should be shown by allowing a drop or two of the alkaline solution to enter, agitating, and taking up more of the liquid. Then a similar tube-ful should be taken, and one end opened under mercury, to show that the pressure is equal to that of the atmosphere. Closing the tube again, it should be guarded by wire-gauze, and then the gases may be caused to combine by the light of burning magnesium. After the explosion and cooling, the tube must be again opened under mercury, to prove that the pressure is still the same, and that there is neither expansion nor contraction produced by the com-

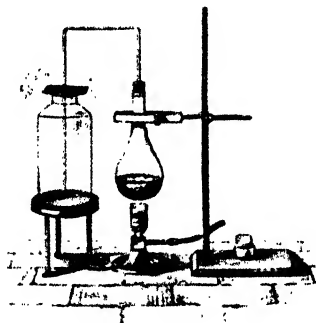


FIG. 22.

bination. Then, open under caustic soda solution, and by introducing a small quantity and agitating, and allowing the tube to be filled completely with the solution, show that the *combined* gases are *completely* soluble in water. These tubes should be very carefully filled. There is some probability of a small quantity of hydrogen or air being in the tube, as it is difficult to expel them altogether.

Next, hydrochloric acid gas may be prepared by action of sulphuric acid on fused common salt (fig. 22), and collected over mercury or by displacement (22). A useful

arrangement for collecting by displacement is a glass plate, perforated, with caoutchouc 'cork' and two tubes, employed as a cover to the jar to be filled (fig. 23). For light gases, enter through tube A; for heavy ones, through tube B. Gas should be driven off quickly, and the issuing air led into water. In the case of soluble gases the cessation or slackening of bubbles indicates the filling of the jar with gas. Let the class understand how a soluble gas, like hydrochloric acid, is collected by displacement. Explain fully the laboratory preparation, and hint at the mode of manufacture. Students too frequently attempt to describe a manufacture which they have not seen, instead of a homely experiment which they have seen.



Fig. 23.

### *Addenda to Lecture III.*

The hardness and other characteristics of natural water form a subject which is reserved for the advanced stage, but an elementary class should see illustrations of the power of water to dissolve gases. Some of these are furnished by the experiments on hydrochloric acid, ammonia, chlorine, sulphurous anhydride, and other soluble gases. A useful and instructive addition to these is to boil a natural water, so as to drive out the dissolved air, and by absorption of oxygen from it to show that oxygen is more soluble in water than nitrogen. (An illustration showing air to be a *mixture*, not a *compound*.) In this experiment it is necessary to fill not only a flask but its leading tube with the water to be boiled, and to place the end of the tube beneath the cylinder in which the gas is to be collected before beginning to warm the water. From the mixture of gases which comes off oxygen is to be absorbed by a piece of phosphorus attached to the end of an iron wire. This requires leaving for a few days, so that the expulsion of air may be shown at one lesson and the result of the

absorption at the next. The oxygen in dissolved air is about two-fifths of its bulk, instead of one-fifth, as it is in ordinary atmospheric air.

Another method of preparing ozone is by placing a little ether at the bottom of a beaker and holding a warm glass rod in the vapour that is given off even at common temperatures. The oxygen liberated by the electrolysis of water always contains ozone enough to react on starch-paper, and sometimes to bleach a weak solution of indigo.

The colour of chlorine cannot well be observed by gas-light; in evening classes a piece of magnesium wire should therefore be burnt, by the light of which its greenish colour is clearly perceptible. A mixture of chlorine and hydrogen, however, is liable to be exploded by this actinic light; if, therefore, a jar of such a mixture happens to have been prepared for a subsequent experiment, it should be covered while the light is used. There are very many experiments designed to show the energy with which chlorine combines with metals. Iron or brass wire may be burnt in the gas, as in oxygen. Chlorine may be passed over iron filings or granulated tin heated in a bulb-tube; the chlorides produced volatilise and condense in a cooler part of the tube. Dutch-metal lowered into a jar of chlorine inflames spontaneously, and is converted into cupric and zinc chlorides. A neater way of showing this is to fill a dry gas-jar with leaves of Dutch-metal loosely packed, and then invert a jar of dry chlorine over it, so that the gas falls upon the metal, which is consumed with a dull red glow. This experiment also illustrates the great density of chlorine.

Among hydrogenous compounds that are spontaneously decomposed by chlorine are turpentine and ammonia, into which may be dipped pieces of filter-paper, which are afterwards introduced into the gas. Carbon is copiously liberated from turpentine, and chloride of nitrogen is (possibly) formed in the reaction with ammonia, causing a dull combustion.

The action of chlorine as a bleaching and disinfecting agent may also be shown by introducing into the gas some paper with both printing and writing upon it: the writing-ink is discharged, and the printing-ink unaffected, its base being carbon. A jar of chlorine should be placed mouth to mouth with one of sulphuretted hydrogen of half its capacity, and the entire destruction of the unpleasant smell noted. The solution of the gas should be

shown to have similar properties to the gas itself, a piece of gold-leaf, for instance, being dissolved by it.

All these experiments ought to be performed in a stink-cup-board, with a good draught, as chlorine is excessively irritating to the lungs.

The preparation of chlorine from a mixture of common salt, manganic dioxide, and sulphuric acid should be shown, as also a method of procuring it in the cold by the action of hydrochloric acid upon bleaching-powder.

The volumetric composition of hydrochloric acid may be shown, if the apparatus mentioned in the text is not accessible, by decomposing a measured volume of the gas with sodium, zinc, or magnesium filings. Half-fill a long test-tube or a similar stouter tube with hydrochloric acid gas over mercury, the level of which should be marked, and introduce into it a pellet of sodium or a few filings of zinc or magnesium loosely screwed up in tissue-paper. Shake up, the thumb firmly stopping the mouth of the tube, and protecting the closed end with the other hand. On reopening the tube under mercury the metal will rise, showing, if the experiment has been carefully performed, that exactly one-half of the gas has disappeared, and the other half can by ignition be recognised as hydrogen.

## LECTURE IV.

THIS appears to be the most convenient place to introduce the consideration of the compounds of chlorine and oxygen. There are not many illustrations adapted for employment before classes. The most noteworthy characteristic of oxides of chlorine—viz., their instability—may be well shown by the explosion, on contact with a hot wire, of chloric peroxide (39). Generate this gas in stout glass cylinders, in which a small quantity of strong sulphuric acid is placed, and in the acid drop a few grains' weight of well-dried and finely-powdered potassic chlorate. Immediate action ensues, and the heavy chloric peroxide drives out the air from the jars, which are loosely covered with pieces of card. Test-tubes may be employed, but they must be protected by a casing of gauze or a spiral of wire. When the gas is perceived by its colour to pervade the vessel completely, a red-hot iron wire may be introduced, and the gas will be decomposed at once, perhaps with a sharp explosion. It is well to have another experiment in reserve to illustrate this same point—viz., the spontaneous combustion of phosphorus under water, in contact with peroxide of chlorine (40). A piece of phosphorus is placed at the bottom of a deep test-glass or beaker containing water, and covered with a few large crystals of potassic chlorate. By aid of a long funnel strong sulphuric acid is now poured directly upon the crystals without mixing with the water. A speedy evolution of gas is the result, which is decomposed with flashes of light immediately on coming in contact with the phosphorus. A solution of *hypochlorous acid* may be pre-

pared before the class (41), by passing a stream of chlorine (by means of the same apparatus already used) through water in which mercuric oxide is suspended. The acid solution should be poured off, and its bleaching powers exhibited. The preparation of *potassic chlorate* should be illustrated (42) by passing chlorine through boiling milk of lime, mixing the product containing calcic chlorate with potassic chloride, and crystallising out the less soluble potassic chlorate. This experiment must be begun one week and finished the next.

*Boron* may now be taken. The manufacture of boric acid in Tuscany is more a matter of description than of illustration, but it will be well to show the precipitation of

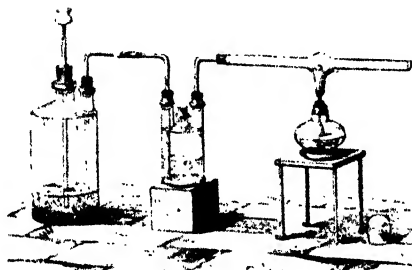


FIG. 24.

boric acid from a hot saturated solution of borax by strong hydrochloric acid (43). On stirring and cooling, innumerable spangles of boric acid are deposited. The peculiar action of boric acid on turmeric-paper may be shown, as well as its feeble action upon litmus solution, and the green tint given to burning alcohol by a mixture of borax and strong sulphuric acid (44).

*Carbon*.—This element may be shown to exist in carbonic dioxide by passing this gas, well dried, over heated potassium in a bulb-tube (fig. 24). Or perhaps it might better be introduced by charring a piece of wood in a test-

tube (45), or by burning a splinter of wood in deficit of air, as in a test-tube. Compare this with the result of burning wood completely, and point out that in the one case the carbon has been prevented from burning away, while in the other it has been allowed to burn away entirely. This explains the rationale of charring wood in billet-heaps, or in cast-iron retorts. Naturally, there is much carbonic dioxide diffused throughout the air, as may be proved by exposing a saucer of lime-water, which absorbs it (46). The gas might even be prepared from atmospheric air, if some substance could be employed to fix it. Mortar thus collects carbonic anhydride, and by acting on old mortar with dilute hydrochloric acid (47), the weaker carbonic acid may be displaced, and its presence proved by its extinction of a light. Whence comes this oxide of carbon in the air? By combustion and respiration. All our ordinary fuels produce carbonic anhydride by their combustion. Show a taper burning in a jar of air over lime-water which is at first clear, but on agitation after combustion becomes clouded (49). To illustrate the production of carbon dioxide by respiration use Faraday's apparatus for inspiring air which passes through lime-water (fig. 25), so as to deprive it of its carbonic anhydride, and expiring it through a separate supply of lime-water (48).

Carbonic acid gas may now be prepared (by displacement, fig. 26) and studied (50). Marble is, perhaps, the best source, and an acid such as hydrochloric, which forms a soluble calcium salt, should be used with it. First show the feeble acid of the gas (52), by shaking up with it a solution of litmus, which becomes of a port-wine tint, strongly contrasted with the brilliant scarlet produced by

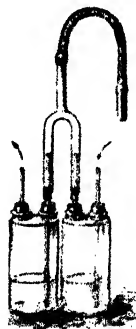


FIG. 25.



stronger acids. 2. The heaviness of carbonic anhydride may be demonstrated in several ways. (a) Pour the gas into a balanced vessel, mouth uppermost (fig. 27). (b) Decant or lift (fig. 28) it from one vessel to another, and test its removal by a taper, or pour it down upon a taper. (c) Blow soap-bubbles, and float them on the surface of a large vessel of the gas, like cork upon water (51). If the gas is drawn off from below (as shown in fig. 29), the bubble sinks. The gradual sinking of a bubble

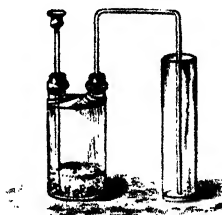


FIG. 26.

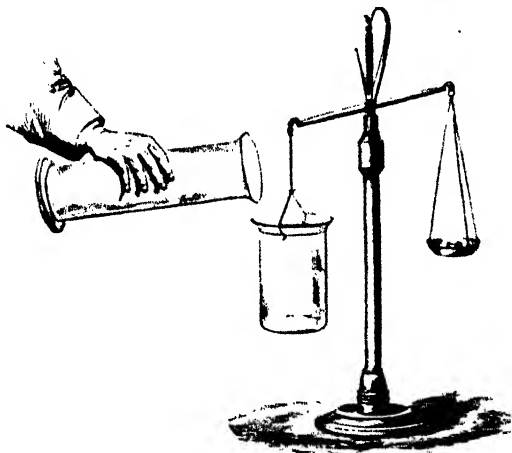


FIG. 27.

and its sudden rebound on reaching the heavier gas are very striking, if this experiment is neatly done. Notice, too, the gradual growing of the bubble till it bursts, by transfusion of carbonic anhydride into its interior. If the

bubble is persistent (as those made of soap and glycerin), it becomes of the same density as the gas, and ultimately sinks. (d) Or the gas may be drawn by a tap from vessel to vessel, or siphoned off; or its shadow may be cast on a white screen, as in the case of hydrogen (Lect. II.), but in this instance the tube from which the gas issues should

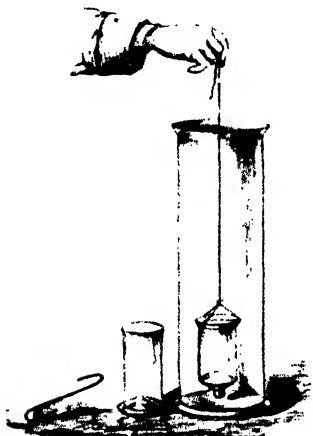


FIG. 28.

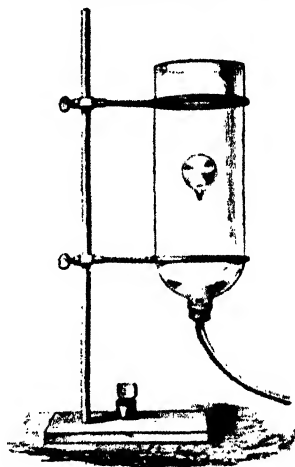


FIG. 29.

be turned upwards. 3. Show the gas to be non-inflammable, and a non-supporter of combustion (53).

Yet this incombustible gas may be transformed into a gas that shall burn. Show this by passing carbonic anhydride over ignited carbon, contained in an iron tube (54). The issuing gas must be washed in caustic alkali, to free it from unchanged carbon dioxide. Thus the inflammable gas carbonic oxide is produced. Another mode of preparation is by decomposing oxalic acid with strong sulphuric acid (55); a mixture is given off of equal volumes of carbonic anhydride and carbonic oxide; the former is separated

by washing in an alkaline solution, and the latter is collected (fig. 30). Perhaps the best mode of preparing the gas, but still with a slight contamination of carbonic anhydride, is to heat well-dried yellow prussiate of potash with nine times its weight of strong sulphuric acid (56). The action requires watching: it is at first slow, then violently quick, as the temperature rises.

Demonstrate the properties of carbonic oxide. 1. Its inflammability (fig. 31) and flame-extinguishing power (57).

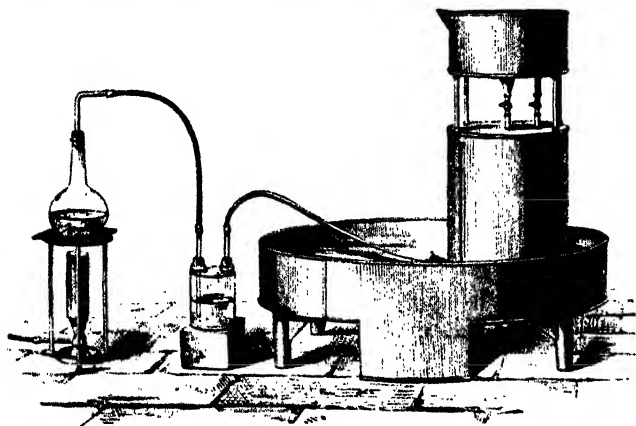


FIG. 30.

2. Its want of action on lime-water (well wash, with caustic soda, the specimen used for this test). 3. Its change on burning into carbonic anhydride; place lime-water in a jar of carbonic oxide; ignite, then shake up (58).

*Nitrogen.*—The consideration of this element may be approached through ammonia, or through atmospheric air; perhaps the last is best suited for an elementary class. Ordinary combustion is supported by the oxygen of the atmosphere, of which the residual gas will not support combustion. A convenient mode of preparing nitrogen from air is by

using some combustible matter. Ordinary combustibles are not available, for two reasons: 1. They do not remove all the oxygen. 2. They introduce a contaminating gas. Phosphorus has neither disadvantage, and is generally employed (59). Use as large a cylinder as is available (fig. 32). Draw attention to the fumes of phosphoric pentoxide, which

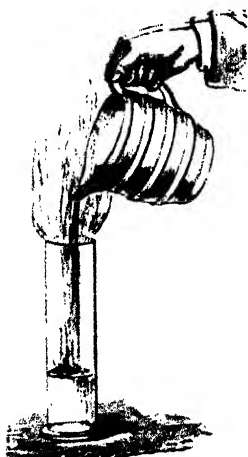


FIG. 31.

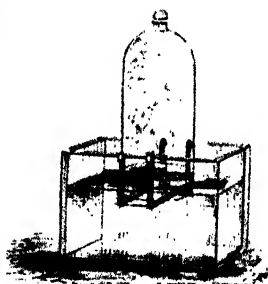


FIG. 32.

are soluble in water. Decant nitrogen into smaller jars, and demonstrate its properties. Nitrogen may also be prepared by heating ammonic nitrite, or what is practically the same thing, from concentrated solutions of sodic nitrite and ammonic chloride, mixed and boiled (60). But the simplest plan, though somewhat hazardous, is by acting with chlorine on concentrated solution of ammonia (61). Caution is necessary, on account of the possible formation of explosive chloride of nitrogen; hence it is advisable to use fresh ammonia for each experiment. Ammonia must be in great excess, turmeric or litmus-paper being kept in the solu-

tion as a guide to the operator. Wide connecting tubes should be used, on account of the formation of ammoniac chloride, which might choke up narrow tubes. Flashes of light attend the decomposition. Excess of ammonia vapour must be absorbed in a wash-bottle containing moistened fragments of glass before collecting nitrogen.

*Properties of Nitrogen.*—1. It will not burn, nor support combustion (62). Yet this statement requires qualification. The combustibility of a gas, as we observe it, depends on its ignition-point being within the reach of our conditions. If the electric spark (which is as much hotter than a blast-furnace as that is hotter than ice) be passed through a mixture of nitrogen and oxygen, they combine, or burn together, and in ten or fifteen minutes red fumes are formed and demonstrate the union (63). At an increased pressure the burning is more rapid; at forty or fifty atmospheres it is almost as fast as that of hydrogen. In this, as in other cases, it is found that the intensity of light is augmented by pressure. In elementary classes this might be inexpensively shown by using a cucumber-glass 14 or 15 inches long, ground at the ends, so that glass plates may be cemented on, a hole being pierced about the middle for inserting a cork with wires for passing the spark. Viewed through this length of tube, red fumes are evident in a few minutes. 2. Show the neutrality of well-washed nitrogen, as well as its want of action upon lime-water (64).

The igniting-point of various substances may here be considered. Some finely divided substances ignite at ordinary temperatures, as various pyrophori, zinc-ethyl, &c. Hofmann's phosphorus-bases are similarly igniscible. Carbonic disulphide is ignited at a temperature far below redness; its vapour may be lighted by a tube of hot oil (310° F.) or a glass rod heated, but still cool enough to be momentarily borne by the fingers. Igniting-points of gases vary, that of hydrogen being lowest, then coal-gas, cannel-gas, and marsh-gas. Nitrogen will not burn, simply because

our ordinary flames do not reach its igniting-point. The oxyhydrogen flame effects some combustion of nitrogen. The old miners' steel mill ignites hydrogen, also coal-gas, but not so easily; cannel-gas not at all, still less marsh-gas, its igniting-point being too high. As these sparks are really burning iron, and therefore have a very high temperature, it is rather surprising that they will not ignite these gases. The subject deserves examination. If three-fourths of the nitrogen in air be replaced by oxygen, a jet of hydrogen burning in the mixture will effect combination to form nitric peroxide. As the igniting-point of nitrogen is higher than the temperature produced by its combustion, the combination only occurs in the path of the electric spark or in contact with flame. If it were otherwise combination would go on throughout the mixture of gases with explosive violence, as in case of a mixture of hydrogen and oxygen. The luminosity of marsh-gas is practically zero, as is also that of hydrogen and carbonic oxide; so their presence in coal-gas in any quantity cannot possibly improve its lighting power.

*Addenda to Lecture IV.*

The oxidising power of potassic chlorate may be utilised in a few other experiments. A few grains of it may be triturated with the same minute quantity of flowers of sulphur in a mortar; a series of detonations indicates the violence of the action. Sulphide of antimony may be employed instead of sulphur; a mixture of this kind was formerly employed as a fulminating powder. In these experiments it is well to protect the hand with an old glove. A minute quantity of amorphous phosphorus placed on a little powdered potassic chlorate detonates on pressure with the blade of a knife. Hypochlorous acid may be more easily prepared by shaking up mercuric oxide in a stoppered bottle containing strong solution of chlorine, and filtering.

In connection with borax it will be well to explain the nature

of the reactions of metallic oxides with the borax bead. Illustrations of this may easily be given to the class, and a few beads prepared beforehand with cobalt, iron, copper, chromium, &c. can be handed round for examination. A very interesting example of reciprocal action may be shown with boric acid. This acid is precipitated from its solutions at low temperatures by hydrochloric and sulphuric acids. At high temperatures, however, boric acid displaces them in turn. This may be shown by heating a mixture of boric acid and sodic chloride in a porcelain crucible, above which, when sufficiently heated, may be held litmus-paper and a glass rod dipped in solution of ammonia or nitrate of silver. The reddening of the test-paper and the formation of white clouds or of a cloudy white precipitate prove hydrochloric acid to be liberated.

A less troublesome mode of showing the existence of carbon in carbonic anhydride is to burn magnesium ribbon in the gas, when flakes of carbon are deposited on the sides of the jar along with a little magnesia, which last may be dissolved away by hydrochloric acid. Similar flakes of carbon may be separated from chalk by heating it, powdered, in a dry test-tube with a piece of phosphorus. A good illustration of the circulation of carbon in nature is afforded by passing a very slow stream of oxygen over ignited charcoal, and collecting a jar of the carbonic acid thus produced, in which magnesium may be burnt, to recover the carbon which was oxidised. The solubility of carbonic anhydride should be illustrated by a bottle of soda-water, from which by a 'champagne-tap' may be drawn more than its own volume of the gas. Here it may be explained that water dissolves an equal volume of carbonic acid gas, at whatever pressure it may happen to be. The solubility of alkaline carbonates in a solution of carbonic acid gas should be shown, and their re-precipitation on addition of lime-water. With respect to the apparent burning of magnesium and potassium in carbonic anhydride, it should be explained that this combustion is effected at the expense of the oxygen of the compound. The temperature of the heated metals must be high enough to decompose it, or the combustion will not take place.

An important illustration of the volumetric composition of carbonic anhydride should be shown if possible. A U-shaped tube is necessary, with a bulb blown in one limb, capable of being closed by a stopper, through which pass two copper wires sustaining a deflagrating ladle of bone-earth containing a minute piece of

charcoal. The bulb being filled with dry oxygen, mercury equalised in each limb, and the level marked, the charcoal is ignited by the galvanic current. The oxygen is thus converted into carbonic an-

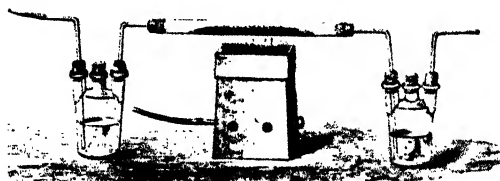


FIG. 33.

hydride, which on cooling is observed to occupy exactly the same volume as the original oxygen.

In preparing carbonic oxide great care should be taken to remove all carbonic anhydride, especially from those jars of the gas designed to show its want of action upon lime-water. When preparing it by the action of sulphuric upon oxalic acid, it will be well to collect a jarful of the mixed gases, and, by submitting this mixture to the action of a caustic alkali, to show that exactly one half of it is absorbed, the remaining half being carbonic oxide. With reference to the usefulness of carbonic oxide generated in smelting furnaces, its reducing powers should be illustrated by passing a stream of the dried gas over heated oxide of copper or of iron, much in the same manner as described already (p. 22) in the case of hydrogen (fig. 33). In this experiment prove the formation of carbonic anhydride by leading it into lime-water.

In preparing nitrogen from atmospheric air attention should be drawn to the proportions in which oxygen and nitrogen occur in the mixture. In measuring this—unless very accurate instruments are available—carbonic anhydride may be omitted from consideration. A useful eudiometer for the purpose is one made out of a piece of half-inch glass tubing, on the principle of a Cooper's receiver, the longer limb being divided into 100 divisions (fig. 34). This instrument is first filled with



FIG. 34.



water. The air to be examined is then introduced, and the level of the water adjusted to the zero of the scale. A few drops of water being now removed from the open end of the eudiometer by a tube, their place is supplied by an equal quantity of solution of potassic pyrogallate; or, what is the same thing, solutions of caustic potash and pyrogallic acid are separately used to refill the open end. The instrument is now closed with the thumb and violently shaken, to promote absorption, and then opened under water, so that the liquid may rise and its level be ascertained. All measurements must be taken after the eudiometer has been immersed in a glass cylinder containing water, so as to counteract the expansion caused by the warmth of the hand, and while the water is standing at the same level both within and without the tube.

## LECTURE V.

IN treating of the compounds of nitrogen and oxygen, *nitrous oxide*, as the simplest, may be taken first. Sometimes, however, it might be well to begin with nitric acid, as the origin, directly or indirectly, of all nitrogen oxides. In preparing nitrous oxide, ammonic nitrate should be first fused, so as to drive off its water. As glass is liable to be overheated, a porcelain dish should be used, and the fused salt, just as it begins to decompose, poured out upon an iron plate to cool; it should then be coarsely powdered. This plan avoids the condensation of steam in the upper part of the flask, and consequent risk of cracking, as well as saves time. When collecting the gas the heat should be moderated after fusion has commenced, to prevent a too stormy evolution of gas. It might be well to show the actual formation of ammonic nitrate by the neutralisation of nitric acid with ammonic carbonate, and crystallising out the product (65). In showing the effect of nitrous oxide upon combustibles (67), the burning body, as sulphur, should be immersed in the gas while feebly burning—it is extinguished; on repeating the experiment with strongly burning sulphur it continues to burn, and with increased brilliancy, almost as if in oxygen (66). The gas itself is really not a supporter of combustion (67). If a burning body generates sufficient heat to decompose it, the liberated oxygen stimulates the flame, the nitrogen taking no part in it. Precisely the same thing may be observed in the case of carbonic anhydride passed over ignited potassium: the oxygen of the gas burns with the metal, and carbon is

deposited. Magnesium ribbon will also burn in the oxygen of carbonic anhydride. The term 'supporter of combustion' is quite relative. Any electro-negative constituent of a body that can be wrested out of its compounds by a more electro-positive element (as oxygen out of carbonic anhydride by potassium) may be considered as a supporter of combustion.

*Nitric oxide* also illustrates this property. It may be prepared in the usual way—by placing copper turnings in

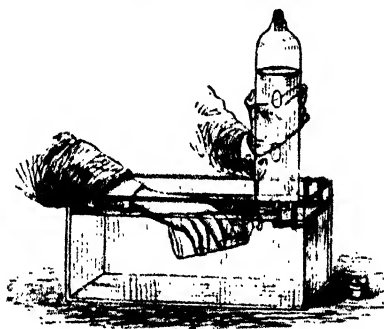


FIG. 35.

a Woulf's bottle, covering them with water, and adding nitric acid through a funnel. Notice that red fumes are first formed, and then, when all the free oxygen in the generating vessels is got rid of, the colourless nitric oxide comes off. A taper is extinguished in this gas (70), so also is feebly-burning phosphorus. But give the phosphorus time to become intensely heated, and it decomposes nitric oxide, and burns brilliantly at the expense of its oxygen—not so brilliantly as in pure oxygen, however, because there is a considerable amount of inert nitrogen which shares in the heat generated. Temperature, as well as density, influences the amount of light given off by burning bodies. Nitric oxide is a test for free oxygen, with which it combines,

forming the ruddy fumes before mentioned. Illustrate this (fig. 35) by decanting into a tall jar standing in the pneumatic trough, and half-full of nitric oxide, an equal volume of oxygen (69). Immediate combination ensues, indicated by the generation of heat and considerable expansion, and subsequent rising of the water, as it dissolves the newly-formed higher ruddy oxide. Repeat this experiment, mixing equal volumes of nitric oxide and nitrous oxide, in which there is no *free* oxygen, and show that no absorp-

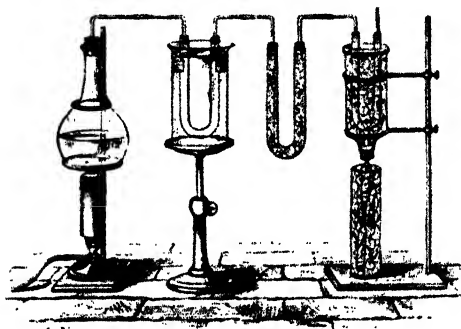


FIG. 36.

tion or formation of brown fumes occurs. This test distinguishes between free oxygen and the only gas likely to be mistaken for it.

*Nitrous Anhydride*.—A small quantity of this should be prepared before the class by the reducing action of arsenious anhydride, or starch, upon strong nitric acid, and collected by displacement (72). A specimen should be shown of the condensed gas (prepared as shown in fig. 36), sealed in a tube, and kept in cold water. The double action of nitrous acid as a reducing and oxidising agent should be shown. Sodid nitrite added to a solution of potassic permanganate acidified with sulphuric acid is reduced and decolorised (73). If added to acidified indigo or magenta,

the colour is discharged by oxidation and nitrous oxide is liberated (74).

*Nitric Peroxide.*—Prepared by heating plumbic nitrate, previously powdered, to decrease decrepitation (75). This decomposes into litharge, left in the flask, oxygen given off, and nitric peroxide, which may be condensed in a U-tube, surrounded by ice and salt.

*Nitric Acid.*—This should be prepared in three ways: 1. By heating a mixture of sulphuric acid with twice its weight of potassic nitrate, the proportions used in manufacture. Show the great heat required, and the risk of loss by decomposition, proved by production of brown fumes and of oxygen. 2. By heating more gently a mix-

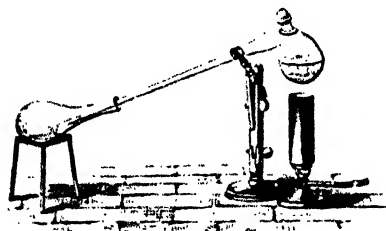


FIG. 37.

ture of sulphuric acid with its own weight of potassic nitrate. In this case a less coloured liquid is produced. Of course the retort must be fitted with a condenser in these cases (fig. 37). 3. By pouring a little concentrated hydroxyl into a jar of nitric peroxide and agitating (77); the colour of the gas disappears, heat is generated, and a true chemical union is effected, precisely analogous to that of hydrogen and chlorine. This may be used as a good illustration of the behaviour of compound radicals, and some explanation of this subject introduced. The acid prepared by each of these methods should be roughly tested, say by addition of copper turnings, and proved to be similar. Illustrate the

oxidising effect of nitric acid upon metals by a little copper or tin (78); upon carbon by deflagrating a mixture of charcoal 15 parts, and nitre 75 parts, or by melting some nitro in a Florence flask, and when it is quite liquid dropping into it a few small pieces of charcoal (79). Then show its want of action upon gold-leaf by shaking up a few leaves in the strong acid (80), and if convenient leaving to stand for a week. Having done the same with gold-leaf and hydrochloric acid (81), the two liquids may be mixed and stirred, when the gold will be dissolved (82). This will introduce *aqua regia*, upon which something may be said.

*Ammonia*.—The more prominent properties of this gas may first be demonstrated. Try with taper and inverted jar (the gas being lighter than air); the flame is first slightly enlarged and then extinguished (85). The enlargement is due to a very slight and evanescent combustion of the gas. Its igniting point, like that of nitrogen, is higher than the temperature produced by its combustion. If heated before lighting, or started from a higher platform of temperature, as it were, it will burn better. Hofmann's gas-furnace may be used with good effect to show this, by a gradual heating till the gas burns, and a gradual cooling till it goes out. Or the gas may be burned in an atmosphere of oxygen by the following arrangement (86). A short tube,  $1\frac{1}{4}$  inch diameter, corked at one end, is taken. Through the cork pass two tubes, one nearly reaching to the open end of the wide tube, from which to burn ammonia, and the other to supply oxygen. A loose packing of cotton-wool is so placed as to diffuse the oxygen pretty equally. On lighting the ammonia it burns with a lambent green flame, which, when the oxygen is turned off, has a short struggle for existence, and then dies out. The solubility in water of ammonia should be shown similarly to that of hydrochloric acid, and with the same precautions (84). Its alkalinity is manifested by reddened litmus or turmeric-paper (87).

Show collection by upward displacement (83, fig. 38), and illustrate the process of manufacture by leading the gas through Woulf's bottles containing water. Heat ammoniac chloride upon platinum foil, to illustrate the volatility of ammonia salts, unless they contain a fixed acid, when the base only, the 'volatile alkali,' is driven off (88).

Now decompose ammonia. First by passing through a red-hot tube; wash the issuing gas in an acid liquor, and use acidified water in the pneumatic trough. The resulting gas has lost the properties of ammonia gas. It is not alkaline, but neutral; it burns readily in air, and it is insoluble in water. If possible decompose by the spark stream in a eudiometer, fitted with a caoutchouc cork, containing a tube with stopcock to admit the gas, and two copper wires, whereby a piece of cupric oxide enclosed in a spiral of platinum wire may be heated; platinum wires for passing the spark are also fused into the glass in the usual manner. Keep the pressure of mercury high, to facilitate decomposition, which must be continued until the volume of gas is just doubled. Then ignite the cupric oxide by the galvanic current; hydrogen is absorbed and nitrogen left. If any ammonia happens to be undecomposed it will be dissolved by the produced water, and the volume of residual gas correspondingly diminished. A suitable piece of cupric oxide can be prepared by calcining a piece of thick copper wire in a current of air. Collect also nitrogen and hydrogen separately by electrolysing one volume strong solution of ammonia mixed with ten volumes saturated solution of common salt. Decompose ammonia gas also by chemical means, by passing over heated potassium or sodium to liberate hydrogen, and by passing chlorine through

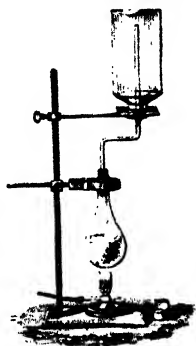
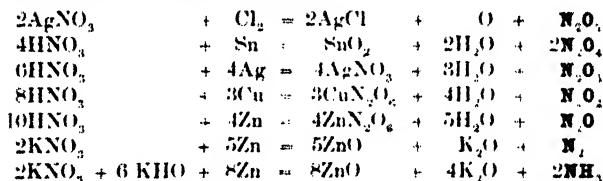


FIG. 38.

its solution to obtain nitrogen, as previously described. Now sum up the volume-relations of ammonia and illustrate the fact  $|\bar{\text{N}}\text{H}_3| = |\text{N}| + |\text{H}||\text{H}||\text{H}|$  by using the cubes already mentioned.

### *Addenda to Lecture V.*

It is a very instructive method of studying the oxy-compounds of nitrogen to begin with nitric acid, and consider the results of its gradual deoxidation. As a matter of fact, nitric acid is, directly or indirectly, the source of all the oxides of nitrogen, and in some cases it is even reduced to nitrogen or ammonia. There is, therefore, a peculiar fitness in this method of bringing a series of facts before the minds of students. The following equations will indicate the mode of treatment :—



The relationship between acids and their anhydrides may here be well illustrated by the nitrogen series, in addition to boric and carbonic anhydrides, already mentioned. The analogy of these with the chlorine series should also be alluded to.

#### *Nitrogen Series.*

	Acids.	Anhydrides.
Nitric	$\text{HNO}_3$	$\text{N}_2\text{O}_5$
Nitrous	$\text{HNO}_2$	$\text{N}_2\text{O}_3$
Hypnitrous (?)	$\text{HNO}$	$\text{N}_2\text{O}$

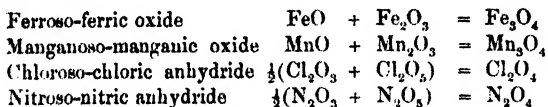
#### *Chlorine Series.*

	Acids.	Anhydrides.
Chloric	$\text{HClO}_3$	—
Chlorous	$\text{HClO}_2$	$\text{Cl}_2\text{O}_3$
Hypochlorous	$\text{HClO}$	$\text{Cl}_2\text{O}$

The analogy between the two peroxides of nitrogen and chlorine should be pointed out, as shown in their similar behaviour



with caustic soda. The combination of two oxides may be illustrated further by reference to the 3-oxides of iron and manganese, already mentioned, and the similar nomenclature shown on the black-board.



The production of ruddy fumes by acting with metals upon nitric acid should be pointed out as a test for the acid. The common test for nitrates by adding strong sulphuric acid and ferrous sulphate may be shown, and further illustrated by absorbing nitric oxide with a solution of ferrous sulphate, and boiling out the gas again. An alternative method of preparing nitric oxide also exemplifies this—namely, by heating a mixture of nitre (125 grains), ferrous sulphate (1,250 grains), and dilute sulphuric acid (4 fluid ounces), containing one-fourth its volume of acid.

A neat way of showing the easy decomposibility of nitric acid with liberation of oxygen is, to pour nitric acid into the bowl of a tobacco-pipe placed in an inclined position, the stem being heated to redness by a Bunsen burner. The evolved gas, which is mainly oxygen, may be collected over water and tested with a lighted taper in the usual way.

The occurrence of ammonia among the products of the destructive distillation of organic bodies containing nitrogen should be illustrated by heating any such substance (as horn, hair, flannel, or lean meat) with caustic soda or soda-lime, when the odour of ammonia is perceived: and turmeric-paper or a rod dipped in hydrochloric acid may be held to the mouth of the tube to afford further proof.

The combination of ammonia with acids (without elimination of any incidental product) to form salts analogous to those of the alkali metals should be well explained and illustrated by symbols on the black-board. The so-called 'ammonium-amalgam' can be shown. A tall glass jar two-thirds full of a strong solution of sal-ammoniac should have poured into it about two ounces of sodium-amalgam. In a few seconds the amalgam will swell out considerably, sometimes rising and floating on the surface of the liquid. The ammonium theory should receive careful

attention, and the intelligent use of the symbol  $\text{Am}$  for  $\text{NH}_4$ , practised in equations where no decomposition of ammonium is involved.



FIG. 39.

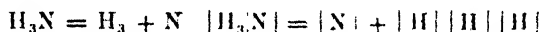
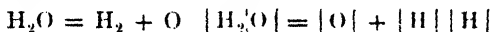
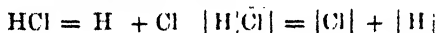
The frequent natural oxidation of ammonia into nitric acid (the reverse of the instance already quoted) should be illustrated. Perhaps the simplest experiment for this purpose is by the 'contact action' of a spiral of platinum wire suspended just above the surface of some ammonia solution in a flask or beaker (fig. 39). Notice the alternate heating and cooling of the wire, and the white fumes of ammoniac nitrite rising from the liquid.

## LECTURE VI.

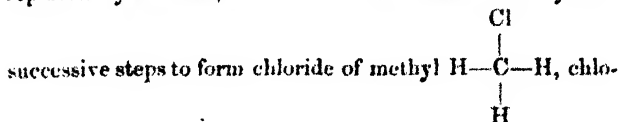
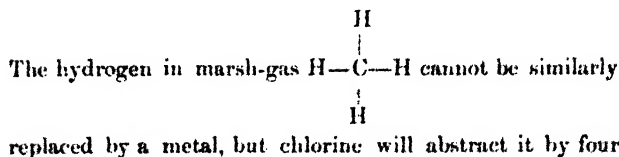
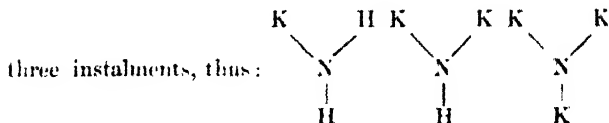
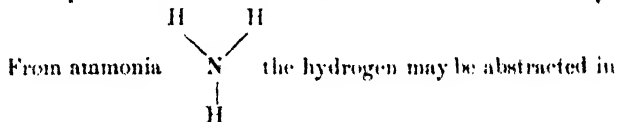
THE doctrine of atomicity may here be taught. In order to fill up a gap in the chain of evidence, it will be well to allude to the constitution of marsh-gas, which, though organic, is sufficiently near the boundary-line to be introduced without doing violence to the order laid down. Show a jar of marsh-gas and demonstrate its properties: it is colourless, transparent, tasteless, inodorous, not appreciably harmful when mixed with air in small quantities, though at 11 or 12 per cent. (exploding proportions) it gives a headache; it is lighter than air, inflammable, and a non-supporter of combustion. Decompose a measured volume by the electric spark. Double its measure of hydrogen is produced, with a deposit of solid carbon, mostly on the negative electrode; but the current needs occasional reversing, to prevent the formation of a bridge of carbon between the poles. The volume of carbon is unknown; it is probably one-fourth that of the hydrogen produced. An element of uncertainty in this demonstration is the formation of a small quantity of acetylene, from partial decomposition of some of the marsh-gas. This increases the luminosity of hydrogen, as may be seen when it is ignited, and should be explained. (It would be a most valuable improvement if coal-gas could have its marsh-gas converted into acetylene, so as to increase its illuminating power.) To render it more evident that marsh-gas contains carbon, mix in a tall glass jar two volumes of chlorine with one volume of marsh-gas (not in sunlight), and ignite. Fumes of hydrochloric acid rise in

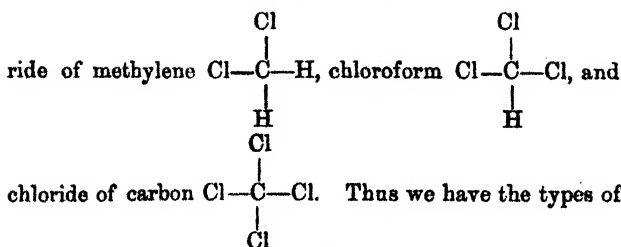
the air, and a dense deposit of carbon remains on the sides of the jar, a little being thrown out as soot.

Now the cubes before mentioned may be employed to illustrate to students in a connected form the facts denoted by the following symbols:—



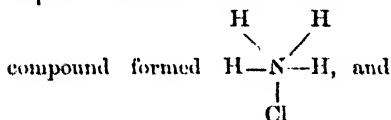
The various replaceability of hydrogen in these compounds should be clearly enforced, and illustrated by glyptic symbols. The hydrogen in hydrochloric acid must be driven out all at once or not at all—thus:  $\text{H}-\text{Cl}$  forms  $\text{K}-\text{Cl}$ . That of water  $\text{H}-\text{O}-\text{H}$  may go out in two halves, forming with potassium  $\text{K}-\text{O}-\text{H}$  and  $\text{K}-\text{O}-\text{K}$  successively.





four classes of elements—monads,  $\text{H}'$  and  $\text{Cl}'$ ; dyads,  $\text{O}''$ ; triads,  $\text{N}'''$ ; and tetrads,  $\text{C}^{iv}$ .

It will be necessary to show also the pentadic nature of nitrogen. Streams of ammonia and hydrochloric acid gases, separate, are invisible, or nearly so. Allowed to mix, they unite to form a dense white cloud of sal-ammoniac. Show this more perfectly by mixing equal volumes of these gases over the mercury-trough (89). They unite with heat and condensation on the sides of the jar, which obscures the rise of the mercury; but the jar can be closed with a glass plate and inverted, to show that the mercury has really filled it. Explain to students the nature of the



how it illustrates the quinquivalence of nitrogen.

*Sulphur.*—Describe its common forms and principal sources. Illustrate its analogy to oxygen, shown by the combustion of metals in its vapour (fig. 40) and specially by the behaviour of certain sulphides on heating, and exemplified by the equations:—

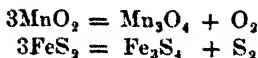


FIG. 40.

Describe the dimorphism of sulphur, proved by its crystallising in one form from solution (fig. 41) and in another from fusion (fig. 42): this last may be shown by fusing in a beaker, piercing two holes in the solidified crust as it cools, and pouring out the liquid from the interior. Show the effect of heat on sulphur (91). Heat gently and cautiously. Fuse first to a thin mobile liquid, of slight viscosity as it approaches its fusion-point. Increasing the heat, observe a thickening and darkening in colour, till the tube or flask may be inverted without spilling the contents. Heat further to boiling-point, the liquidity increases and viscosity decreases. On now pouring into water the plastic variety is obtained (90).



FIG. 41.

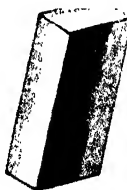


FIG. 42.

A better mode is to distil from a retort into cold water. Mention the gradual return of sulphur from the plastic to its ordinary condition. Specimens of the plastic variety made during a lesson may be distributed among students, to observe this fact at leisure and at home.

*Sulphuretted Hydrogen.*—Prepare from ferrous sulphide and dilute sulphuric acid, and collect in the usual way (92). Burn the gas from a jet, and hold near the flame a glass rod dipped in ammonia (93), to prove the formation of sulphurous acid gas. Show its acidity by wet litmus-paper (94). Show its decomposition by sulphurous anhydride, applying two jars mouth to mouth, putting the lighter gas ( $\text{SH}_2$ ) uppermost, then invert (95). Moisture is necessary, and a little pentathionic acid is formed. Show its decomposition similarly by chlorine—a little dichloride of sulphur is

formed here (96). A most important experiment (fig. 43) is to pass the gas through solutions of pure cupric sulphate, arsenious anhydride, tartar emetic, plumbic acetate, and zincic sulphate free from iron (97). Explain the production

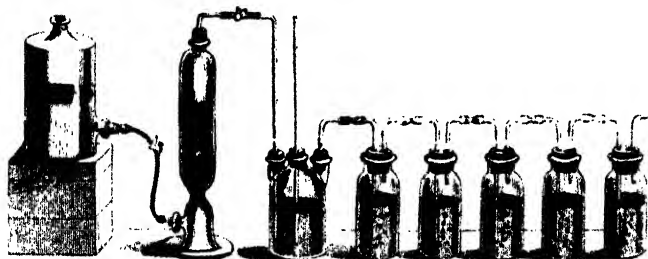


FIG. 43

of precipitates—brown, yellow, orange, black, and white—and point out the importance of this reaction in analysis. Give a classification of the principal metals based upon their precipitability by sulphuretted hydrogen, and urge upon students the necessity of fully mastering it.

*Sulphurous Anhydride.*—Prepare by the action of copper or mercury on sulphuric acid; wash and dry by passing through sulphuric acid, and collect by displacement (98). Show acid properties with litmus-paper moistened (99). Liquefy by condensing in a tapped U-tube fitted in an inverted deflagrating jar packed with ice and salt (100). Draw off the liquid sulphurous anhydride in a test-tube. Show the deposition of hoar-frost outside the tubes, and the boiling of the liquid by the warmth of the fingers. Show that water freezes on being mixed with the liquid anhydride—unless, indeed, a solid hydrate is produced. It may be better, perhaps, to dip a small test-tube containing water into the liquid, so that the rapid evaporation from the outside may freeze the water inside. Demonstrate the flame-extinguishing power of the gas (101), and its solubility in water in the usual way (102). Show its bleaching powers

by pouring a solution into infusion of roses ; show that the colour is restored on addition of a stronger acid, as sulphuric or hydrochloric (103). The bleaching of sulphurous anhydride is thus markedly distinct from that of chlorine.

Sulphurous anhydride is easily oxidised to sulphuric acid ; it is difficult, indeed, to get a solution of it without a trace of the higher acid. This fact may be illustrated :

1. By leaving a solution of sulphurous acid exposed to air.  
2. By adding nitric acid to a similar solution, and warming (104). 3. By adding to a jar of sulphurous anhydride gas a few drops of strong hydroxyl and agitating (106). Demonstrate the identity of these products by precipitating with baric chloride.

It is remarkable how students at the May examination, 1870, misunderstood the first question in the paper : ' You have given to you some sulphur, water, and nitric acid : describe how you would make sulphuric acid from these materials ? ' The question obviously referred to the oxi-

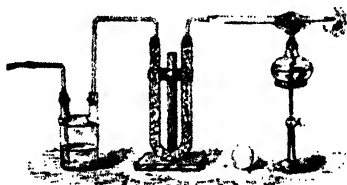


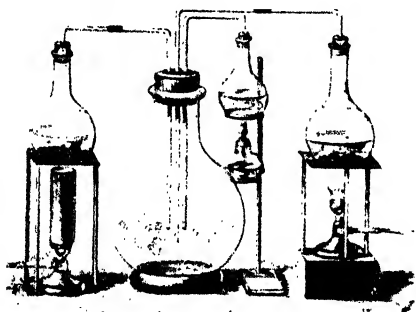
FIG. 44.

of sulphurous anhydride by means of nitric acid. Yet the majority of the candidates who attempted it gave a long account of the manufacture of sulphuric acid, with all the details which they could recollect of the leaden chambers, &c. This gives a striking illustration of the necessity of intelligence as well as information to enable a student to come out well in an examination. Not only ability to answer a question, but to *understand* it first, is wanted.

*Sulphuric Acid.*—Sulphur only forms one oxide directly



—namely, sulphurous anhydride; but it can be made to take up another atom of oxygen, and form sulphuric anhydride. This combination can be effected (fig. 44) by passing a mixture of two volumes sulphurous anhydride and one volume oxygen, both well dried, over heated spongy platinum or platinised asbestos (105). A low red heat is necessary. A table illustration (fig. 45) of the manufacture of sulphuric acid should be given (107).



The 'lead chamber' is represented by a large flask, into which are led streams of oxygen or air from a gas-holder, and sulphurous anhydride, nitric oxide, and steam, from small flasks in which they are generated. Keep the supply of moisture small, so as to procure, if possible,

a few white crystals  $\begin{cases} \text{SO}_2(\text{NO}_2) \\ \text{O} \\ \text{SO}_2(\text{NO}_2) \end{cases}$ ; then increase the

moisture and secure their decomposition with reproduction of much nitric trioxide. The experiment requires care, and should be well practised beforehand. Show the affinity of sulphuric acid for water by placing a small quantity of strong syrup in a large beaker on a plate, and adding to it, suddenly, an equal volume of the strong acid. Sudden dehydration leaves a huge mass of carbon (108).

*Hyposulphurous Acid*.—Add hydrochloric or sulphuric acid to a solution of sodic hyposulphite, and show, after a brief interval, the deposition of sulphur and evolution of sulphurous anhydride (109). Infer from this, first, the isolation; and, secondly, the great instability of hypsulphurous acid.

The experiments employed to illustrate this course are those which are detailed in the Syllabus of the Department,\* as absolutely necessary for students to see. The whole of them should be made, amplified, and multiplied, if possible, before an elementary class. None of them can be omitted with safety. In addition, teachers ought to strive to appreciate the importance of requiring their pupils to take notes during class lessons, and of themselves looking over and revising these notes as frequently as possible. This is a most valuable adjunct to teaching. A pupil who is made to take notes not only has the lecture or lesson much more firmly fixed in his mind, but he acquires the habit of expressing his ideas in writing, and will, on this account alone, be much more likely to work a satisfactory paper in the annual examination. Pupils ought also to be encouraged, if not required, to write out at home an abstract of the lessons from the notes they have taken while the lessons were in progress. Questions should also be given out at the close of a lesson, and the answers when brought in examined by the teacher. This of course involves some trouble, but an earnest teacher will not be content to confine himself to giving an hour's lesson, and then letting his pupils take their chance of picking up such information as they require. The more a teacher can enter into the individual work and wants of his students the better it will be both for them and for himself.

\* See Appendix.

*Addenda to Lecture VI.*

The important modern doctrine of atomicity has not been formally mentioned till nearly the end of this course, but there are many occasions when in passing a brief allusion may be made to it. By deferring its full consideration until late the advantage is gained of having furnished the student with a multitude of facts which may be employed in illustration by a simple effort of memory. The teacher will find it well for this part of his subject to study carefully Hofmann's 'Modern Chemistry' throughout, and Chapter III. of Frankland's 'Lecture Notes'—not necessarily to lay their substance before his students, but to provide himself with a number of useful helps in explaining what is undoubtedly a difficult subject to beginners. In all explanations of this kind copious use should be made of the black-board and of symbols. With regard to symbols, though it is a convenience for all the members of a class to use one system, the matter is not of such vital importance as to render it undesirable to use modifications occasionally. In fact, a variety of symbols may sometimes be really valuable, *e.g.* in describing sulphuric acid as the result of the peroxidation of sulphuretted hydrogen, the empirical formula  $\text{H}_2\text{SO}_4$  may well be employed, while the rational formulæ  $\text{H}_2\text{O}.\text{SO}_3$  and  $\text{SO}_2.\text{HO}_2$  or  $\text{SO}_2(\text{HO})_2$  may express its preparation from sulphuric anhydride and water, and from sulphurous anhydride and hydroxyl, respectively.

It is advisable also not to be over careful in restricting the information given to a class too closely to the Syllabus in the Directory. Bromine and iodine, for instance, are not included in the elementary course, but it would be a serious omission in a teacher to neglect giving a brief account of the analogies which these elements present to iodine. Silicon, again, might be briefly treated in connection with the allotropic modifications of its congeners, boron and carbon. Treatment of this kind gives a completer character to science-teaching than a too slavish adherence to the prescribed course would result in.

Another point which is liable to be omitted is, to teach students something of the common chemicals in every-day use. Strictly speaking, these come in at the advanced stage, under their respec-

tive metals. But common oxides, hydrates, chlorides, nitrates, and sulphates are properly mentioned under their respective non-metallic constituents. Their trivial names, systematic names, and formulæ should be given to students, and specimens should be shown. If the pupils can be persuaded to try a few simple experiments with them—such as examining them on charcoal before the blowpipe flame—it will be a good preparation for the advanced stage, which perhaps is in itself rather too heavy a course for a single year. The following list may be useful. Water of crystallisation is purposely omitted from the formulæ.

Systematic Names	Trivial Names		Formulæ
<i>Oxides and Hydrates.</i>			
Sodic hydrate	Caustic soda	NaHO	OHNa
Potassic hydrate	Caustic potash	KHO	OHK
Ammonic hydrate	Liquor ammoniæ	AmHO	OHAm
Calcic oxide	Caustic or quick-lime	CaO	CaO
Calcic hydrate	Slacked lime	CaH <sub>2</sub> O <sub>2</sub>	CaHO
Baric oxide	Baryta	BaO	BaO
Strontic oxide	Strontia	SrO	SrO
Magnesian oxide	Magnesia	MgO	MgO
Zincic oxide	Zinc white, flowers of zinc, philosopher's wool	ZnO	ZnO
Mercuric oxide	Red precipitate	HgO	HgO
Mercurous oxide	'Black wash'	Hg <sub>2</sub> O	Hg <sub>2</sub> O
Plumbic oxide	Litharge, massicot	PbO	PbO
Triplumbic tetroxide	Red lead, minium	Pb <sub>3</sub> O <sub>4</sub>	PbPb
Stannic oxide	Putty-powder	SnO <sub>2</sub>	SnO <sub>2</sub>
Aluminic oxide	Alumina, emery	Al <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>
Arsenious oxide	White arsenic	As <sub>2</sub> O <sub>3</sub>	As <sub>2</sub> O <sub>3</sub>
Ferric oxide	Coleothar, jeweller's rouge, crocus-powder, hematite	Fe <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>
Chromic oxide	Permanent green	Cr <sub>2</sub> O <sub>3</sub>	Cr <sub>2</sub> O <sub>3</sub>
Manganic dioxide	Pyrolusite, black oxide of manganese	MnO <sub>2</sub>	MnO <sub>2</sub>
<i>Chlorides.</i>			
Sodic chloride	Common salt, rock-salt, sal gem	NaCl	NaCl
Potassic chloride	Sylvine, Stassfürth salt	KCl	KCl
Ammonic chloride	Sal-ammoniac	AmCl	AmCl
Argentichloride	Horn-silver	AgCl	AgCl
Calcic chloride		CaCl <sub>2</sub>	CaCl <sub>2</sub>

Systematic Name	Trivial Name	Formulae	
<i>Chlorides—continued.</i>			
Zinc chloride	Burnett's disinfecting fluid	ZnCl <sub>2</sub>	<b>ZnCl<sub>2</sub></b>
Mercuric chloride	Corrosive sublimate	HgCl <sub>2</sub>	<b>HgCl<sub>2</sub></b>
Mercurous chloride	Calomel	Hg <sub>2</sub> Cl <sub>2</sub>	<b>Hg<sub>2</sub>Cl<sub>2</sub></b>
Plumbic chloride	Horn-lead	PbCl <sub>2</sub>	<b>PbCl<sub>2</sub></b>
Stannous chloride	Tin salts	SnCl <sub>2</sub>	<b>Sn<sup>''</sup>Cl<sub>2</sub></b>
Aluminic chloride	'Chloralum'	Al <sub>2</sub> Cl <sub>6</sub>	<b>'Al<sup>'''</sup>Cl<sub>6</sub></b>
Ferric chloride	Used in 'tincture of steel'	Fe <sub>2</sub> Cl <sub>6</sub>	<b>'Fe<sup>'''</sup>Cl<sub>6</sub></b>
Antimonious chloride	Butter of antimony	SbCl <sub>3</sub>	<b>SbCl<sub>3</sub></b>
<i>Other Chlorine Salts.</i>			
Sodic hypochlorite	Eau de Javelle	NaOCl	<b>OClNa</b>
Potassic hypochlorite	Labarraque's disinfecting fluid	KOCl	<b>OClK</b>
Calcic chloro-hypochlorite	Bleaching-powder	CaClOCl	<b>CaClOCl</b>
Potassic chlorate		KClO <sub>3</sub>	<b>{ OCl Al</b>
Sodic nitrate	Cubic nitre, Chili salt-petre	NaNO <sub>3</sub>	<b>NO<sub>2</sub>Nao</b>
Potassic nitrate	Nitre, saltpetre, sal prunella, Bengal salt-petre	KNO <sub>3</sub>	<b>NO<sub>2</sub>Ko</b>
Ammonic nitrate		AmNO <sub>3</sub>	<b>NO<sub>2</sub>Amo</b>
Argentic nitrate	Lunar caustic	AgNO <sub>3</sub>	<b>NO<sub>2</sub>Ago</b>
Argentic sulphide	Silver-glance	Ag <sub>2</sub> S	<b>SAg<sub>2</sub></b>
Zincic sulphide	Zinc-white, blende	ZnS	<b>ZnS<sup>''</sup></b>
Cadmie sulphide	Cadmium yellow	CdS	<b>CdS<sup>''</sup></b>
Mercuric sulphide	Cinnabar, vermilion	HgS	<b>HgS<sup>''</sup></b>
Plumbic sulphide	Galena	PbS	<b>PbS<sup>''</sup></b>
Stannous sulphide	Tin pyrites	SnS	<b>SnS<sup>''</sup></b>
Ferrous sulphide		FeS	<b>FeS<sup>''</sup></b>
Ferric sulphide	Iron pyrites	Fe <sub>2</sub> S <sub>3</sub>	<b>Fe<sup>''</sup>S<sub>2</sub></b>
Diarsenious disulphide	Realgar, red orpiment	As <sub>2</sub> S <sub>2</sub>	<b>As<sup>''</sup>S<sub>2</sub></b>
Arsenious sulphide	Yellow orpiment	As <sub>2</sub> S <sub>3</sub>	<b>As<sup>''</sup>S<sub>3</sub></b>
Antimonious sulphide	Black antimony	Sb <sub>2</sub> S <sub>3</sub>	<b>Sb<sup>''</sup>S<sub>3</sub></b>

Systematic Name	Trivial Name	Formulae	
<i>Sulphates, &amp;c.</i>			
Sodic sulphate	Glauber's salt	$\text{Na}_2\text{SO}_4$	$\text{SO}_2\text{Na}_2$
Potassic sulphate	Sal polychrest, sal de duobus	$\text{K}_2\text{SO}_4$	$\text{SO}_2\text{K}_2$
Hydropotassic sulphate	Sal enixum	$\text{KHSO}_4$	$\text{SO}_2\text{HoKo}$
Magnesian sulphate	Epsom salt	$\text{MgSO}_4$	$\text{SO}_2\text{Mgo}''$
Calcic sulphate	Alabaster, gypsum, selenite, plaster-of-Paris	$\text{CaSO}_4$	$\text{SO}_2\text{Cuo}''$
Baric sulphate	Heavy spar, permanent white	$\text{BaSO}_4$	$\text{SO}_2\text{Bao}''$
Zincic sulphate	White vitriol or copperas	$\text{ZnSO}_4$	$\text{SO}_2\text{Zno}''$
Cupric sulphate	Blue vitriol or copperas, bluestone	$\text{CuSO}_4$	$\text{SO}_2\text{Cuo}''$
Plumbic sulphate	Lead vitriol	$\text{PbSO}_4$	$\text{SO}_2\text{Pbo}''$
Ferrous sulphate	Green vitriol or copperas	$\text{FeSO}_4$	$\text{SO}_2\text{Feo}''$
Dipotassic aluminic tetrasulphate	Potash or common alum	$\text{K}_2\text{Al}_2(\text{SO}_4)_4$	$\text{S}_4\text{O}_8\text{Al}_2\text{Ko}_2$
Sodic thiosulphate	Hyposulphite of soda, antichlor	$\text{Na}_2\text{S}_2\text{O}_3$	$\text{BSO}\text{Na}_2$
<i>Carbonates.</i>			
Sodic carbonate	Barilla, washing soda	$\text{Na}_2\text{CO}_3$	$\text{CO}\text{Na}_2$
Hydric sodic carbonate	So-called 'carbonate of soda'	$\text{NaHCO}_3$	$\text{COHoNa}$
Potassic carbonate	Potash, pearlash, salt of tartar	$\text{K}_2\text{CO}_3$	$\text{CO}\text{Ko}_2$
Hydric potassic carbonate	Sal eratus	$\text{KHCO}_3$	$\text{COHoKo}$
	Sesquicarbonate of ammonia, smelling salts, Preston salts	$2\text{Am}_2\text{O} \cdot 3\text{CO}_2$	
Magnesian carbonate	So-called 'magnesia'	$\text{MgCO}_3$	$\text{COMgo}'$
Calcic carbonate	Chalk, marble, limestone, calcspar	$\text{CaCO}_3$	$\text{CO}\text{Cuo}''$
Zincic carbonate	Calamine	$\text{ZnCO}_3$	$\text{CO}\text{Zno}''$
Plumbic carbonate	White lead ore	$\text{PbCO}_3$	$\text{CO}\text{Pbo}''$
Ferrous carbonate	Spathic iron ore	$\text{FeCO}_3$	$\text{CO}\text{Feo}''$
Cupric carbonate	Malachite	$\text{CuCO}_3$	$\text{CO}\text{Cuo}''$
<i>Borate.</i>			
Sodic diborate	Borax, tincal	$\text{Na}_2\text{B}_4\text{O}_7$	$\text{B}_4\text{O}_7\text{Na}_2$



## APPENDIX.

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### I. SYLLABUS OF ELEMENTARY COURSE IN INORGANIC CHEMISTRY.

(From the 'Science Directory'.)

Pupils presenting themselves for examination will be expected to possess a knowledge of the following subjects:—

Definition of chemistry. Simple and compound matter. Different modes of chemical action. Combining weights. Volume weights. Principles of chemical nomenclature. Symbolic notation. Graphic notation. Chemical formulæ. Chemical equations. Atomicity of elements. Simple and compound radicals. Definition of a compound radical. Classification of all elements into metals and non-metals, into positive and negative elements. Classification according to atomicity.

French and English systems of weights and measures. Conversion of English into French weights and measures. The cuth and its uses.

*Hydrogen*.—Its preparation and properties.

*Chlorine*.—Preparation of chlorine from hydrochloric acid. Analysis and synthesis of hydrochloric acid. Properties and reactions of hydrochloric acid.

*Oxygen*.—Its preparation and properties. Allotropic oxygen or ozone. Formation and reactions of water. Preparation and properties of hydroxyl. Compounds of chlorine with oxygen and hydroxyl.

*Boron*.—How it occurs in nature. Its allotropic modifications. Boric anhydride. Boric acids.

*Carbon*.—Its preparation and allotropic forms. Preparation and properties of carbonic oxide and carbonic anhydride.



*Nitrogen*.—Its preparation and properties. Compounds of nitrogen with oxygen and hydroxyl. Compound of nitrogen with hydrogen. Ammonia. Ammoniac salts.

*Sulphur*.—Its properties and allotropic modifications. Compounds of sulphur with positive elements. Compounds of sulphur with oxygen and hydroxyl.

## II. EXTRACT FROM A REPORT BY DR. FRANKLAND.

In conclusion, I have to state that it would in my opinion be desirable to call the attention of such science-teachers as give instruction in Chemistry to the circumstance, that the unsatisfactory results of the examinations in the elementary stage of inorganic chemistry are obviously due chiefly to the want of sufficient experimental illustrations in the classes. It would be well to bring to the notice of such teachers that the performance of the following experiments, at least, ought to be witnessed by every pupil who comes up in the elementary stage, and that for the future it will be assumed that such has been the case:—

1. Ignition of platinum wire and of magnesium wire in air, to show effect of chemical action in the second case (1).\*

2. Transformation of liquids and gases into solids and *vice versa* by chemical action (2, 5).

3. Ignition of phosphorus by red-hot bar of iron placed at a distance of several inches.

4. Attraction of a suspended wooden rod by an electrically excited glass tube held at a distance of several inches (25).

5. A glass rod moistened with concentrated sulphuric acid held close to a small heap of a mixture of sugar and potassic chlorate produces no effect, but inflames the mixture as soon as the rod is brought into actual contact with it.

6. An example of direct chemical union:—Combination of hydrogen and chlorine by heat (4).

7. Chemical displacement:—Precipitation of copper from a solution of cupric sulphate by a bright plate of iron (3).

8. Mutual chemical exchange:—Add solution of potassic iodide to solution of mercuric chloride (3).

\* These figures refer to the list of apparatus next given.

9. Re-arrangement of elements in a compound:—Coagulation of albumen by heat (2).

10. Resolution of a compound into its elements, or into two or more less complex compounds:—Heat mercuric oxide and show oxygen and mercury produced (34).

11. Electrolysis of water, with demonstration of properties of the separated gases (21, 49).

12. Preparation of hydrogen by the action of sodium upon water (5).

13. Preparation and collection of hydrogen from zinc and dilute sulphuric acid (8).

14. Preparation and collection of hydrogen from zinc and solution of caustic soda (12).

15. Burn jar of hydrogen mouth upwards, and another with the mouth downwards (5).

16. Pour hydrogen upwards from one jar into another (5).

17. Extinguish a burning taper in hydrogen (5).

18. Preparation and collection of chlorine from manganic oxide and hydrochloric acid (10, 11).

19. Bleach carmine-paper in the gas (5).

20. Electrolysis of solution of hydrochloric acid. Collect gases separately, and show their properties (8, 21, 49).

21. Burn jet of hydrogen in chlorine (6, 35).

22. Prepare hydrochloric acid gas from common salt and sulphuric acid. Collect over mercury or by displacement of air (10, 11).

23. Show by test-papers alkalinity of solution of potash, acidity of solution of hydrochloric acid, and neutrality of liquid produced by the mixture of these solutions in suitable proportions (3).

24. Extinguish taper in hydrochloric acid gas (5).

25. Show solubility of hydrochloric acid gas in water (7).

26. Prepare and collect oxygen from mercuric oxide, potassic chlorate, a mixture of potassic chlorate and manganic oxide, and by the transmission of chlorine and steam through a red-hot tube (9, 10, 11, 15, 16, 34, 45, 48).

27. Burn a taper in oxygen, and show re-kindling from glowing wick (6).

28. Combustion of phosphorus in oxygen (14, 39).

29. Combustion of bundle of steel wire in stream of oxygen (36, 46).

30. Explosion of mixture of oxygen and hydrogen (22).
31. Show formation of water from jet of hydrogen burning in oxygen (8, 35).
32. Show neutral reaction of water.
33. Show formation of ozone by action of moist phosphorus upon air. Show action of ozonised air upon paper imbued with starch and potassic iodide (23).
34. Preparation of hydroxyl by passing a stream of carbonic anhydride through water containing baric peroxide in suspension (3, 8, 9).
35. Heat hydroxyl in test-tube, and show evolution of oxygen (2).
36. Add argentic oxide to hydroxyl, and show production of oxygen and metallic silver (2).
37. Wash with solution of hydroxyl paper discoloured with plumbic sulphide (41).
38. Wash with solution of hydroxyl white oil-paint similarly discoloured (41).
39. Prepare chloric peroxide ( $\text{Cl}_2\text{O}_4$ ) in test-tube, and explode it with a hot wire (2).
40. Add sulphuric acid to a mixture of phosphorus and potassic chlorate under water (5, 24).
41. Prepare hypochlorous acid by agitating chlorine with mercuric oxide and water (10, 11, 16).
42. Transmit current of chlorine through boiling milk of lime, add potassic chloride to filtered product, and then crystallise out potassic chlorate (17).
43. Preparation of boric acid from borax and hydrochloric acid (17).
44. Flame of a solution of boric acid in alcohol (23).
45. Preparation of charcoal from wood in test-tube (2).
46. Show crust upon lime-water after exposure to air (28).
47. Add hydrochloric acid to pieces of old mortar, and show that carbonic anhydride is evolved (3).
48. Breathe through lime-water (3).
49. Burn candle in glass cylinder filled with air, and show formation of carbonic anhydride by lime-water (6).
50. Prepare and collect carbonic anhydride from limestone, chalk, or marble, and hydrochloric acid (8, 9).

51. Show that soap-bubbles filled with air float on carbonic anhydride (27).
52. Pour solution of litmus into jar of carbonic anhydride (5).
53. Immerse lighted taper in jar of carbonic anhydride (5).
54. Pass carbonic anhydride through an iron tube filled with charcoal and heated to redness. Show the inflammability of the carbonic oxide produced (5, 8, 9, 54).
55. Prepare and collect carbonic oxide from a mixture of oxalic acid and sulphuric acid (1, 10, 11).
56. Prepare and collect carbonic oxide from a mixture of sulphuric acid and yellow prussiate of potash (11).
57. Inflame jar of carbonic oxide, and immerse lighted taper in the gas (5).
58. Agitate lime-water with carbonic oxide, and show that no turbidity is produced; inflame the gas, agitate again, and demonstrate the production of carbonic anhydride (5).
59. Prepare nitrogen by burning phosphorus in atmospheric air (26, 37).
60. Prepare and collect nitrogen from ammonic nitrite, or from a mixture of potassic nitrite and ammonic chloride (13).
61. Prepare and collect nitrogen by passing chlorine into strong solution of ammonia (10, 11, 20).
62. Immerse a burning taper in nitrogen (5).
63. Pass electric sparks through air in a small vessel containing litmus-paper (32, 49, 50).
64. Show neutrality of nitrogen.
65. Prepare and collect nitrous oxide from ammonic nitrate. Show production of ammonic nitrate from nitric acid and ammonic carbonate (3, 15).
66. Show that feebly burning sulphur is extinguished in nitrous oxide, and that sulphur strongly ignited continues to burn in the gas with augmented brilliancy (14, 30).
67. Immerse a burning taper in nitrous oxide (5).
68. Prepare and collect nitric oxide from copper and nitric acid (8, 9).
69. Add nitric oxide to air in a jar over water (6, 7).
70. Immerse a burning taper in nitric oxide (5).
71. Show that feebly burning phosphorus is extinguished in nitric oxide, and that strongly ignited phosphorus burns in it brilliantly (14, 30).

72. Preparation of nitrous anhydride from nitric acid and arsenious anhydride (13).

73. Show the reducing action of nitrous acid by adding a solution of potassic permanganate to an acidified solution of a nitrite (3).

74. Show the oxidising action of nitrous acid by adding a solution of a nitrite to acidulated water tinted with magenta (3).

75. Prepare nitric peroxide ( $N_2O_4$ ) by mixing nitric oxide and oxygen (5).

76. Prepare nitric acid from potassic nitrate and sulphuric acid (13, 18).

77. Prepare nitric acid by the direct combination of nitric peroxide and hydroxyl (5).

78. Pour nitric acid upon copper clippings (3).

79. Detlagrate a mixture of nitre and charcoal (15).

80. Add strong nitric acid to gold-leaf (3).

81. Add strong hydrochloric acid to gold-leaf (3).

82. Mix the two last-named liquids together and show that the gold-leaf then dissolves (3).

83. Prepare gaseous ammonia from a mixture of ammoniac chloride and slacked lime. Collect over mercury or by displacement (15).

84. Demonstrate solubility of ammonia in water (7).

85. Immerse a taper in gaseous ammonia (5).

86. Burn a stream of gaseous ammonia at the end of a hot tube (15, 45).

87. Show alkalinity of ammonia.

88. Demonstrate volatility of ammoniac chloride (38).

89. Show production of ammoniac chloride from gaseous ammonia and hydrochloric acid gas (5).

90. Prepare plastic sulphur (17, 18).

91. Melt sulphur in test-tube and show changes as the temperature increases (1).

92. Prepare and collect sulphuretted hydrogen from ferrous sulphide and dilute sulphuric acid (8, 9).

93. Burn jet of sulphuretted hydrogen, and hold over the flame a glass rod moistened with ammonia.

94. Show acidity of sulphuretted hydrogen (5).

95. Decompose sulphuretted hydrogen by sulphurous anhydride (5).

96. Decompose sulphuretted hydrogen by chlorine (5).
97. Pass sulphuretted hydrogen gas through an aqueous solution of each of the following substances :—Arsenious acid, cupric sulphate, plumbic acetate, tartar-emetic, and zincic sulphate (29).
98. Prepare sulphurous anhydride by the action of copper upon sulphuric acid. Collect over mercury or by displacement (10, 11).
99. Show action of sulphurous anhydride on litmus-paper (5).
100. Condense sulphurous anhydride in glass tube immersed in a mixture of snow and salt (10, 11, 30).
101. Immerse taper in sulphurous anhydride (5).
102. Demonstrate solubility of sulphurous anhydride in water (5).
103. Bleach infusion of rose-leaves by sulphurous acid, and then restore the colour by addition of dilute sulphuric acid (3).
104. Convert sulphurous acid into sulphuric acid by—1. Exposing its aqueous solution to the air; and, 2, by heating its aqueous solution with nitric acid (13).
105. Demonstrate the formation of sulphuric anhydride by passing sulphurous anhydride and oxygen over ignited spongy platinum (10, 11, 31, 36).
106. Show the formation of sulphuric acid by the direct union of sulphurous anhydride and hydroxyl (5).
107. Prepare sulphuric acid by mixing sulphurous anhydride, oxygen or air, nitric peroxide, and steam, in a flask (12, 10, 36).
108. Add one volume of concentrated sulphuric acid to two volumes of strong syrup of white sugar placed in a capacious vessel (17).
109. Demonstrate the spontaneous decomposition of free hyposulphurous acid, by adding dilute sulphuric acid to a solution of sodic hyposulphite (3).

According to § XLV. of the Directory special extra payments are made on account of students who show a good knowledge of experimental chemistry or laboratory practice. This knowledge is at present tested by questions set with the ordinary paper in May. In the elementary stage the course of instruction to which the questions are confined is the preparation of the elements and compounds above enumerated, and the of experimentally demonstrating their properties. These

tions are, as much as possible, so framed as to prevent answers being given by pupils who have obtained their information merely from books and oral instruction.

### III. LIST OF APPARATUS FOR TEACHING INORGANIC CHEMISTRY.—ELEMENTARY STAGE.

(A set corresponding with this list is on exhibition in the South Kensington Museum.)

1. *Bunsen Burner, with Rose*.—For burning a mixture of coal-gas and air, the latter being admitted through the small holes at foot. The rose is used for gently heating a glass or porcelain vessel, as in Exp. 55 and 91; without the rose, a long, narrow, intensely hot flame is produced, suitable for ignition, as in Exp. 1, but not for direct application to glass or porcelain vessels.

2. *A Dozen Test-tubes*.—(Exp. 2, 35, 36, 39, 45.)—For exposing various substances to a moderate degree of heat.

3. *Three Test-glasses on Feet*.—(Exp. 7, 8, 23, 34, 47, 48, 65, 73, 74, 78, 80, 81, 82, 103, 109.)—For showing the effect of mixing various solutions.

4. *Two Small Strong Cylinders, 8 in.  $\times$   $\frac{3}{4}$  in.*—For showing the formation of hydrochloric acid (Exp. 6). One is filled with hydrogen, the other with chlorine, both being closed with glass discs; they are then placed mouth to mouth, chlorine uppermost, the discs withdrawn, the gases allowed to mix perfectly, and the jars separated, when the application of a flame to the mouth of each cylinder causes an explosion, with production of hydrochloric acid.

5. *Two Cylinders on Feet, 12 in.  $\times$  1 in.*—(Exp. 2, 12, 15, 16, 17, 19, 24, 40, 52, 53, 54, 57, 58, 62, 67, 70, 75, 77, 85, 89, 94, 95, 96, 99, 101, 102, 106.)—For demonstrating the properties of gases.

6. *Two Cylinders on Feet, 15 in.  $\times$  2 in.*—(Exp. 21, 27, 49, 60.)—For similar purposes.

7. *A Cylinder on Foot, 30 in.  $\times$  3 in.*—(Exp. 25, 69, 84.)—For demonstrating the solubility of certain gases in water. The cylinder must be filled with dry gas and closed with a stout glass plate, grasped firmly, and the mouth dipped into water, the plate

being slid off so as to allow a very small jet of water to enter the cylinder as the absorption proceeds.

8. *Two-necked Woulff's Bottle, fitted with Thistle Funnel and Delivery Tube.*—For the preparation of gases not requiring the application of heat, as hydrogen, carbonic anhydride, nitric oxide, and sulphuretted hydrogen. (Exp. 13, 34, 50, 54, 68, 92.) The tube of the funnel must dip into the liquid in the bottle.

9. *Two-necked Woulff's Bottles, fitted up as Wash-bottles for Washing Gases.*—For freeing gases from traces of the acids used in their preparation, by passing them through water or alkaline solutions. The inlet tube should just dip beneath the surface of the liquid. By placing strong sulphuric acid instead of water in these bottles any gas passed through will be freed from moisture. (Exp. 26, 34, 50, 54, 68, 92).

10. *Three-necked Woulff's Bottles fitted up as Wash-bottles, with Tube as Safety Tube.*—(Exp. 18, 22, 26, 41, 55, 61, 98, 100, 105.)—For similarly washing very soluble gases, as hydrochloric acid and ammonia. The inlet and safety tubes should just dip beneath the surface of the washing liquid. The safety tube permits of the entrance of air, in case of any running back of water through absorption of gas, and so restores the equilibrium of pressure.

11. *Large Flasks fitted with Cork, Thistle Funnel, and Delivery Tube.*—For the preparation of gases from liquids by the aid of heat. Flame should not be allowed to come in contact with the glass, a piece of iron-wire gauze or a sand-bath being interposed between the flask and the source of heat. (Exp. 18, 22, 26, 41, 55, 56, 61, 98, 100, 105).

12. *Smaller Flasks, fitted up as No. 11, and used for similar purposes.* (Exp. 14, 107).

13. *Small Flask fitted with Cork and Delivery Tube.*—(Exp. 60, 72, 76, 104.)—For heating substances, generally solids, and collecting products of decomposition. Without the tube this may be used as a receiver to condense nitric acid, in Exp. 76.

14. *Large Flasks with Wide Necks.*—For burning phosphorus in oxygen, &c. (Exp. 28, 66, 71).

15. *Three Florence Flasks, with Corks and Delivery Tubes.*—(Exp. 26, 65, 79, 83, 86.)—For use when the naked flame must be applied to a glass vessel. Being cheap, the fracture of these flasks is of slight consequence.



16. *Flask with Cork and Two Tubes, used for Washing Gases.*—(Exp. 26, 41.)—For purposes similar to those described in No. 9. Specially, as in Exp. 26, for passing a gas through hot water, so as to mix it with steam.

17. *Large Beaker.*—(Exp. 42, 43, 90, 108.)—For use when hot solutions are required in open vessels, or when substances are mixed, which by their action evolve heat. To be heated upon gauze or a sand-bath.

18. *Retorts, one large, one smaller.*—(Exp. 76, 90.)—For use in distillation, as of nitric acid.

19. *Large Flask, 1-2 Gallons, with Cork and Five Tubes passing into it, one reaching just through the Cork, the remainder to the Centre of the Flask.*—To illustrate the manufacture of sulphuric acid: oxygen or air, nitric oxide, sulphurous anhydride, and steam being admitted through the longer tubes, and an aspirator attached to the shorter one, to maintain a constant current. (Exp. 107).

20. *Two-necked Bottle fitted as Wash-bottle, but with wide Inlet Tube.*—(Exp. 61.)—For decomposing ammonia by chlorine. A deposit of sal-ammoniac is formed, which would choke a narrow inlet tube.

21. *Voltammeter to decompose Water and collect the Gases separately.*—(Exp. 11, 20.)—May be used also to electrolyse aqueous hydrochloric acid and ammonia. The battery, No. 49, is employed for this purpose.

22. *Bell-jar with Stopcock, and Glass Vessel for Bell-jar to float in.*—(Exp. 30.)—To be filled with a mixture of two volumes of hydrogen and one of oxygen. The gas can be transferred by downward pressure of the jar and opening the stopcock into a bladder or collodion balloon, which is then exploded by contact with flame.

23. *Stoppered Cylinder on Foot.*—(Exp. 33.)—For the preparation of ozone, by leaving a piece of freshly-cut phosphorus for thirty or forty minutes in a shallow layer of water at the base of the cylinder. The phosphorus should rise above the water, so as to be partly in contact with the air enclosed in the cylinder.

24. *Long Thistle Funnel Tube.*—(Exp. 40.)—For conveying sulphuric acid to the bottom of a glass of water, so as to procure the combustion of phosphorus in contact with potassic chlorate.

Used also for pouring liquids into non-tubulated retorts without wetting the insides of the necks.

25. *Glass Tube and Silk Rubber*.—(Exp. 4.)—For producing electricity.

26. *Large Tubulated Bell-jar*.—(Exp. 59.)—The jar, being closely stoppered, is placed over a capsule, floating on water, containing ignited phosphorus. When the phosphorus ceases to burn the jar is depressed, so as to equalise the level of the water within and without. The stopper being then removed, the residual gas can be tested and shown to be nitrogen.

27. *Tubulated Aquarium*.—(Exp. 51.)—To be filled with carbonic anhydride through the tubulure at bottom until the gas overflows. Soap-bubbles filled with air will float when they are allowed to fall into the glass vessel.

28. *Shallow Glass Dish*.—(Exp. 46.)—For exposing a large surface of lime-water to the air of the room wherein a lesson is being given, to prove the presence of carbonic anhydride therein.

29. *Series of Two-necked Bottles*. For passing  $\text{SiH}_2$  through various solutions of metallic compounds to produce sulphides. (Exp. 97.) The bottles should contain aqueous solutions of arsenious anhydride, cupric sulphate, plumbic acetate, tartar-emetic, manganous chloride, and zincic sulphate.

30. *A Tube with Stopcock at bend, surrounded by Glass Vessel to contain Freezing Mixture*.—(Exp. 100.)—For the liquefaction of sulphurous anhydride by a mixture of ice and salt.

31. *Combustion Tube containing Spongy Platinum*.—(Exp. 105.)—Through the heated tube is passed a mixture of two volumes of sulphurous anhydride and one volume of oxygen. They combine to form sulphuric anhydride, which produces dense white fumes when it issues from the tube into moist air.

32. *Globe with Two Platinum Wires for passing a Stream of Electric Sparks through Air*.—(Exp. 63.)—Under the stimulus of the intense heat of the spark the constituents of the air in the globe combine to form ruddy fumes of nitrous anhydride and nitric peroxide, which redden moist litmus-paper.

33. *Clock Glass*.—(Exp. 44.)—To contain an alcoholic solution of boric acid, which, on ignition, burns with a characteristic green-edged flame.

34. *Tube for Heating Mercuric Oxide*.—To show its decomposition into mercury and oxygen. (Exp. 10, 20.)—The mercury

condenses in the bend, the gas passing onwards to a pneumatic trough.

35. *Jet from which to Burn Hydrogen*.—(Exp. 21, 31.)—To be attached by a flexible tube to a hydrogen apparatus (No. 8), and, the gas being lighted, lowered into a jar of chlorine or oxygen.

36. *Gasholder*.—(Exp. 29, 105, 107.)—For storing gas for some time, or supplying it in considerable quantity when required for experiment. May be used also as an aspirator. (Exp. 107).

37. *Porcelain Capsule*.—(Exp. 59.)—For use with the bell-jar No. 26 in the preparation of nitrogen from atmospheric air.

38. *Platinum Foil and Wire*.—(Exp. 88.)—The foil serves to show the fixedness or volatility of substances when exposed to a red heat; the wire is used for preparing coloured beads with metallic oxides and fused borax.

39. *Two Deflagrating Spoons*.—(Exp. 28, 66, 71.)—For showing the combustion of sulphur, phosphorus, sodium, &c. in oxygen and chlorine.

40. *Pestle and Mortar*.—For pulverising various substances.

41. *Broad Camel-hair Brush*.—(Exp. 37, 38.)—For brushing a solution of hydroxyl over discoloured white paint, so as to restore its original whiteness.

42. *Iron Tripod Stands*.—For supporting flasks, &c. over lamps.

43. *Two Retort Stands*.—For a similar purpose.

44. *India-rubber Tubing, assorted*.—For making connections between the tubes of various pieces of apparatus, as in Exp. 54, where Nos. 8, 9, 45, and 10 are used. It may be cut into lengths of two or three inches for this purpose.

45. *Clay Furnace for Burning Coke, with Iron Tube to pass through*.—(Exp. 26, 54, 86.)—For exposing a gas to a red heat.

46. *Blowpipe Jet*—(Exp. 20.)—Fitted to the gasholder No. 36, a powerful blast of oxygen may be obtained, and used to show the burning of a bundle of steel wires, by allowing the jet of gas to blow through the flame of a spirit-lamp.

47. *Pneumatic Trough*.—For collecting gases insoluble or but slightly soluble in water.

48. *Porcelain Tube to pass through Furnace*.—(Exp. 26.)—For use instead of the iron tube in No. 45 in cases where, as with chlorine, the use of iron is inadmissible. In heating a mixture of steam and chlorine the tube should be packed with broken porce-

lain or pieces of pumice, so as to afford as large a surface as possible.

49. *Five-cell Grove's Battery.*—(Exp. 11, 20.)—For electrolysing water, hydrochloric acid, and ammonia. The full power is needed for this work. When used with an induction coil the number of cells should be adapted to the size of the coil.

50. *Induction Coil.*—(Exp. 63.)—For effecting the direct combination of nitrogen and oxygen by the intense heat of the electric spark. Also for decomposing ammonia-gas and marsh-gas by the same agency. A coil of the size exhibited will work well with five cells of the battery No. 49.

This list of apparatus is not to be considered as complete. It barely suffices for the performance of the list of experiments just given, and the teacher who restricts himself to it will work under difficulties. Duplicates of most of the glass articles ought certainly to be obtained, and also a good stock of flasks, retorts, reduction bulbs, tubing, gas jars, and similar things in constant use. Some pieces of apparatus, as the gas generators hereafter mentioned, ought to be kept ready for use at a moment's notice, and a small stock of some of the gases may be usefully kept in half-gallon bottles fitted as gas-holders with two tubes (like a wash-bottle) with clips or stopcocks.

Where analysis is taught, a Kipp's sulphuretted hydrogen generator (fig. 46) should be used. Ferrons sulphide in small lumps is placed in the central globe, and prevented from falling into the lower one by a piece of sheet lead fitting loosely round the funnel tube (*a*). Dilute sulphuric or hydrochloric acid is poured into the upper globe until it is full and the liquid also occupies one half of the lower one. This can be regulated by the cock fitted at *d*. To generate the gas, open the cock, when the acid rises into the middle globe and acts on the ferrous sulphide. To stop the operation, close the cock, when the pressure of the gas drives

back the acid, and the gas ceases to be generated. With a little care, this apparatus works very well.

Another apparatus for this gas may be fitted up as shown in fig. 47. Without the wash-bottle c and the funnel in a, two or three sets may be kept for the preparation of such gases as hydrogen and carbonic anhydride, which are

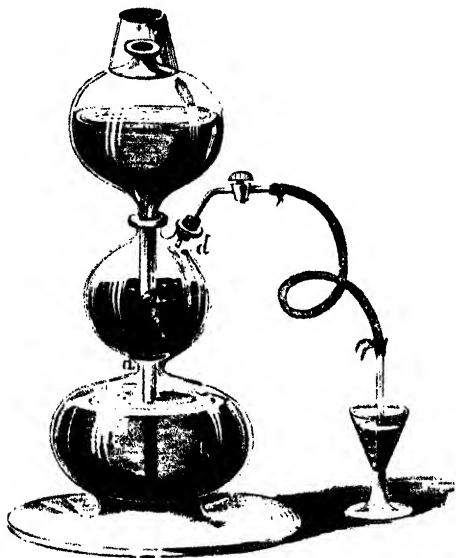


FIG. 46.

always in requisition. To produce gas, A must be higher than B; to stop the action, B is placed above A. Two pint bottles can be thus fitted for half-a-crown and a little trouble, and they are always ready for use.

A third very useful form of apparatus for similar purposes is shown in fig. 43. The vessel holding the ferrous sulphide is called an *eprouvette*, and is sometimes used, packed with calcic chloride, for drying large volumes of gases.

Our list of apparatus would hardly be sufficient without

an allusion to the usefulness of diagrams. A list of the elements with their atomic weights, classified according to their atomicity (see Frankland's 'Lecture Notes,' p. 32) should be in every class-room, and other useful tables should be shown frequently. These may be purchased, printed upon paper, or the teacher may stencil them himself upon calico, which is far preferable, the diagrams being more per-

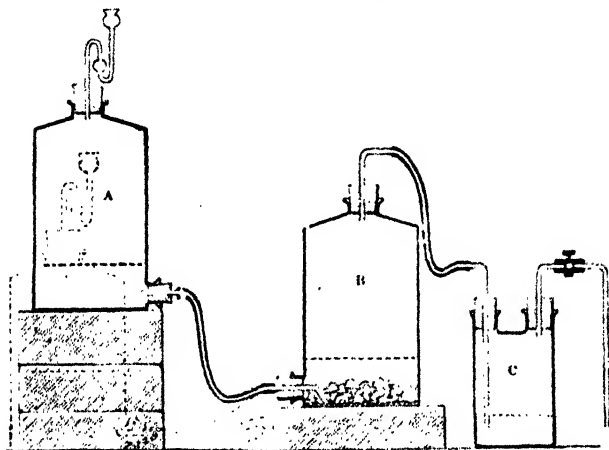


FIG. 47.

manent. The cost of stencil plates is about four shillings per alphabet, and of brushes only a few pence. The brush should be short and stiff, and not too full of ink. The following is a recipe for an aniline black ink which is almost indelible. The gum tragacanth is dissolved by heat in the proportion of 20 parts by weight to 600 parts of water :—

## SOLUTION I.

Gum tragacanth solution	.	.	.	26 parts by weight
Hydrochlorate of aniline	.	.	.	25 ..
Ammonic chloride	.	.	.	4 ..

## SOLUTION II.

Gum tragacanth solution	. . . . .	65 parts by weight
Potassic chlorate	. . . . .	3       "
Cupric chloride	. . . . .	6       "
Water	. . . . .	26       "

These solutions are mixed in equal parts a few hours before use, and shaken up well. The diagrams must be hung up to dry for a day or two as soon as completed, and then washed in the usual way. On no account are they to be folded until washed, or they will 'set off' unpleasantly. If in stencilling a mistake is made, the letter can be washed out by immediate vigorous brushing with strong soap and water, but it is less troublesome to stitch over the error with a piece of calico and stencil afresh.

#### IV. LIST OF CHEMICAL APPARATUS FOR SPECIAL IMPORTANT ILLUSTRATIONS.

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3. Apparatus for the determination of vapour densities by Gay-Lussac's process and by Dumas' process.
4. Apparatus for showing that hydrogen and chlorine do not contract in uniting to form hydrochloric acid.
5. Apparatus for the decomposition of ammonia by spark current, and for the subsequent combustion of the liberated hydrogen by cupric oxide.
6. Apparatus for the decomposition of marsh-gas.
7. Apparatus for showing that by the combustion of carbon and sulphur in oxygen no alteration of volume takes place.
8. Siemens' ozone apparatus.
9. Galvanometer.
10. Thermopile.
11. Daniell's hygrometer.

12. Eudiometer to estimate oxygen in air.
13. Diffusion tube.
14. Oxyhydrogen blowpipe and gas-bags.
16. Apparatus to prepare acetylene from hydrogen and carbon.
17. Twenty cells of Grove's battery.
18. Apparatus for preparing acetylene from coal-gas.
19. Model apparatus for coal-gas.
20. Apparatus for exposing equal volumes of hydrogen and marsh-gas to various temperatures and pressures.



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